Vol. 31 No. 12 NUTS & VOLTS • WIZARD WANDS • COMPOST MONITORING • PROTOTYPE THIS • 16-BIT EXP December 2010

PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

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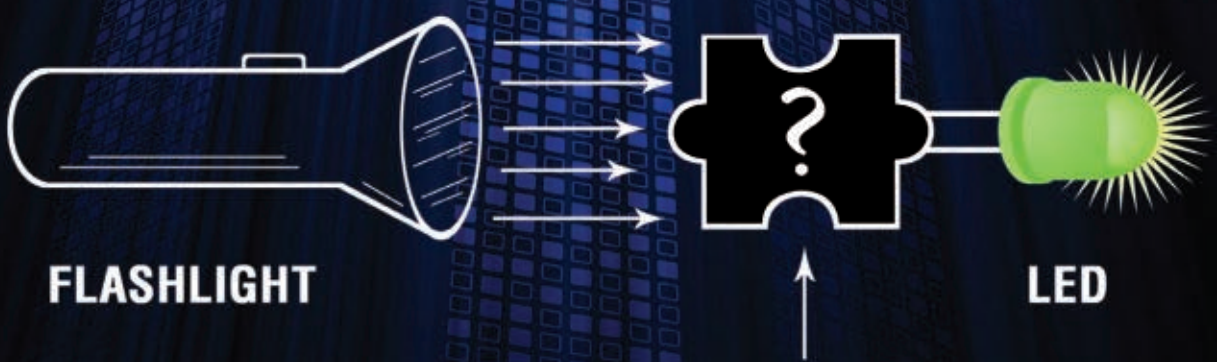


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The puzzle was created by Forrest M. Mims III

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# December
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You can also visit article pages from back issues at **www.nutsvolts.com**. Just select the ***Back Issues*** tab from the ***Magazine*** drop down menu, click the Table of Contents link, and the article name.

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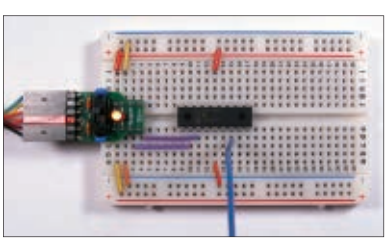

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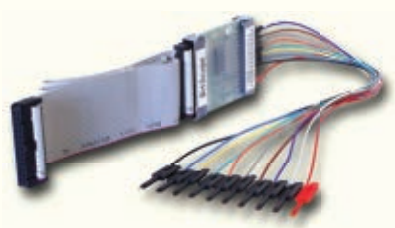

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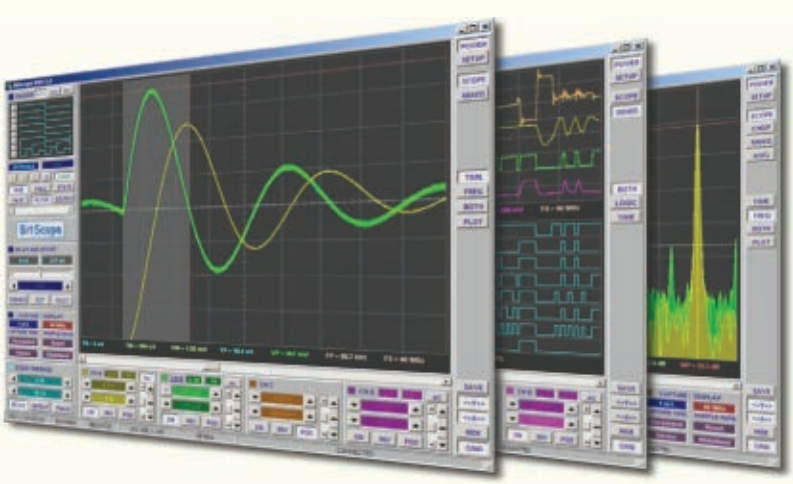
Other software options include WaveMeter and BitGen for synthesis and analysis applications or BitLib for customized applications & integration with many third-party numerical analysis tools.



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by Bryan Bergeron, Editor

# DEVELOPING PERSPECTIVES

## What are the "Best" Components for Your Project?

A common theme in many of the emails I receive is a call for help in identifying the best components — from resistors to microprocessors — for experimenting with electronics. The answer, of course, is that it depends. It sounds like a cop-out, but the 'best' components for general experimentation — much less a specific project — really do depend on a variety of objective and subjective measures.

Two major determinants in defining what constitutes best are cost and application. You're obviously not going to spend $100 on a precision op-amp that's part of an LED blinker circuit. Similarly, it would be unwise to use an electrolytic capacitor rated at 6 VDC in at 12.6 VDC circuit.

If you're just starting out and want to have a supply of components around so that you don't have to wait two weeks for parts to arrive when you get the urge to build something, the application area — say, RF or audio — readily defines the types of components you should consider. No need to splurge on a high-powered RF MOSFET when a low-powered, audio MOSFET will do.

In addition to addressing specific needs, there are several systematic approaches to building up a supply of components. One is to find a book or website that explains specific classes of components. *The Art of Electronics* by Horowitz and Hill comes to mind for a book on components. It's a bit dated, but still a goldmine of information.

Another approach is to rely on product data from a major online supplier such as Mouser or Digi-Key. Online or print catalogs from these and similar parts suppliers are great because they highlight the key parameters for classes of components. For example, let's consider electrolytic capacitors. If you log in to Digi-Key and search for 'electrolytic capacitor,' you'll get a table of selection criteria that you can use to further define your search. It turns out that the selection criteria are usually the most important for a given component class.

Returning to our search for electrolytic capacitors, the table produced by Digi-Key includes capacitance, voltage rating, tolerance, lifetime at temperature, operating temp range, special features, ripple current, equivalent series resistance, impedance, and a variety of physical parameters. If your application is an output filter for a DC power supply, then you'll be primarily concerned with voltage rating, capacitance value, and ripple current. However, if you're using the capacitor as part of an RC timing element, then you're going to pay particular attention to the tolerance rating. If you don't know what the individual parameters mean, it's an easy enough exercise to look up, say, equivalent series resistance on Wikipedia.

Now, let's perform a search for 'diode,' sub-category 'bridge rectifier.' The criteria now include peak reverse voltage, DC forward current, speed of recovery, and reverse recovery time. If you're building a power supply, you're probably going to be concerned primarily with peak reverse voltage and DC forward current. Again, if you're unfamiliar with a term, it's a great time to Google it.

Before I place the order for a component, I make a practice of reading the official datasheet. The datasheet which is published by the component manufacturer usually contains too much information to be used as a screening tool, but is a great sanity check. Once you've narrowed your selection down to two or three components, official datasheets can help you make your final decision. Datasheets are especially helpful when they

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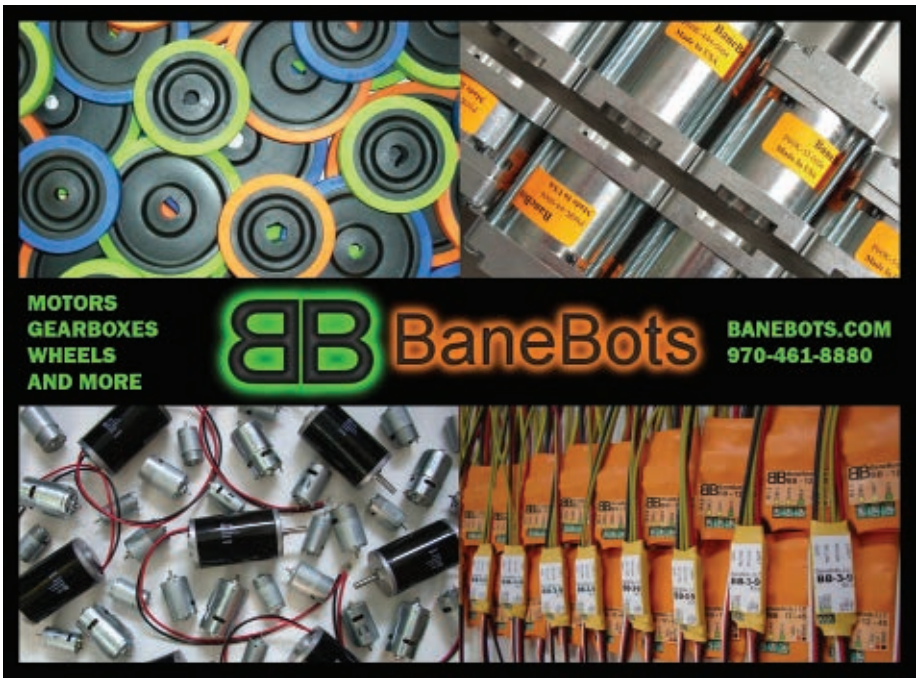
contain example circuits that show the practical application of components. They're also great at identifying general application areas, such as RF, audio, or power.

Another approach to component selection worth noting is to explore existing circuits. That is, to tear down whatever you can get your hands on. Want to know what kind of electrolytic capacitors go into a good AC-DC power supply? Take one apart. Given the output voltage range of the supply, how conservatively are the output capacitors rated? Unless you're dealing with a super cheap supply, you'll find the capacitor max voltage rating of about twice the maximum expected output voltage. After a few teardowns, you'll not only get a feel for the specific components you need to have on hand, but also practical information on component layout and overall circuit design. **NV**



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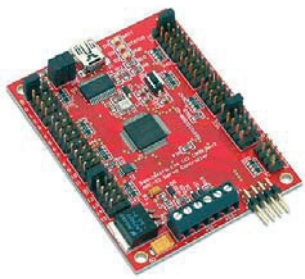

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# TECH KNOWLEDGEY 2010

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

## ADVANCED TECHNOLOGY

### TOUCHABLE 3D TV

■ Reshaping the Earth in i 3 Space.

Some folks at Japan's National Institute of Advanced Industrial Science and Technology (AIST, **www.aist.go.jp**) have announced development of — in technical terms — a combined haptic interface using sensory illusion and 3D television, i.e., a system in which the user experiences the feeling of touch and resistance in a 3D virtual reality. In layman's terms, 3D feelyvision has arrived.

The "i 3 Space" technology was presented at CEDEC 2010 (a conference for game developers) who are likely to be among the first to put it to commercial use. Basically, what you have is the usual 3D video system with a major twist: The system not only projects images, it creates the feeling of touch and resistance in the air by providing continuous vibration patterns that your nerves mistake for actual tactile and kinesthetic sensations. It even lets you stretch, bend, and otherwise deform the images.

Beyond implementation in gaming, the technology holds great promise for things like 3D CAD (wouldn't it be nice to touch your design before it's even built?), surgical simulation for medical training, and sensory experiences that heretofore have been pretty much limited to the holodeck on the Enterprise. In fact, you're probably already thinking of a few that would be too embarrassing to describe herein. In any event, AIST is highly open to suggestions. "Since this technology has been independently developed by AIST, we strive to start a venture business. In the future, we intend to reduce the size of the system, enhance its functionality, and apply it to smart phones and other devices. We also plan to carry out development and field tests for various possible applications through collaborations with manufacturers of domestic electrical appliances and information technology devices." Just drop a line to AIST president Tamotsu Nomakuchi. ▲

### TRANSMITTERS CAN TAKE THE HEAT

Most electronics work fine at normal ambient temperatures, but a shortcoming of silicon-based devices is that they tend to disintegrate when exposed to extreme heat. An NIST study, for example, found that handheld radios typically used by firefighters list maximum operating temperatures as 140°F (60°C), but conditions in a blaze can get as high as 500°F (260°C). This means that if you happen to live inside an active volcano, on the surface of Mercury, or in certain parts of Texas in the summertime, you're out of luck. However, researchers at the UK's Newcastle University (**www.ncl.ac.uk**) have developed silicon-carbide components that can withstand up to 1,650°F (900°C) and are working to integrate them into an iPhone-size wireless sensor that can operate nicely in such extreme environments as volcanos, jet engines, and power plants.

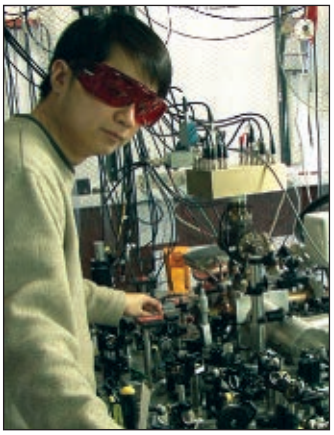
Dr. Alton Horsfall, who heads up the SiC effort, explained, "At the moment, we have no way of accurately monitoring the situation inside a volcano and, in fact, most data collection actually goes on post-eruption. With an estimated 500 million people living in the shadow of a volcano, this is clearly not ideal ... We still have some way to go, but using silicon carbide technology we hope to develop a wireless communication system that could accurately collect and transmit chemical data from the very depths of a volcano." In addition, the devices are designed to withstand extremes of pressure and radiation, making them suitable for a variety of harsh environments. "If someone sets off a bomb on the underground, for example, this will still sit on the wall and tell you what's going on ... Increasingly, mankind is spreading out into harsher and more extreme environments as our population grows and we explore new areas for possible sources of energy and food in order to sustain it. But with this comes new challenges, and this is why research into extreme technologies is becoming ever more important." ▲

### ANOTHER WIN FOR RELATIVITY

Using what the National Institute of Standards and Technology (NIST, **www.nist.gov**) rates as the world's most precise clock (accurate to within 1 s in 3.7 billion years), scientists have again demonstrated that Einstein's "twin paradox" is correct. In one experiment, they set up two of the clocks with one about a foot higher in elevation than the other. Because the height difference made the upper clock slightly less subject to gravitational forces, it ran faster. One

conclusion that we can draw from this is that your head is genuinely older than your feet, so at least when you can't think anymore, maybe you can still dance. The difference won't be especially pronounced, though, as your head will be only about 90 billionths of a second older even as you approach age 80. This may seem of little practical interest but, in fact, "Such comparisons of super-precise clocks eventually may be useful in geodesy, the science of measuring the Earth and its gravitational field, with applications in geophysics and hydrology, and possibly in space-based tests of fundamental physics theories," noted physicist Till Rosenband, leader of the clock team. ▲

*Photo courtesy of J.Burrus/NIST.*



■ NIST Researcher James Chin-wen Chou with the world's most precise clock, based on the vibrations of a single aluminum ion.

# COMPUTERS AND NETWORKING

■ HP's ProLiant Microserver, geared for small business.

## SERVER FOR BOTTOM FEEDERS

If you think your company is too small to need a server, Hewlett Packard wants to change your mind. The company recently introduced its first ProLiant MicroServer specifically designed for companies with fewer than 10 employees. A part of HP's "Just Right IT" portfolio, the new MicroServer is said to provide considerable benefits over a standard bunch of networked PCs, including faster access to shared files and applications; increased performance via expandable, pluggable drives; enhanced security and control over access to confidential files; and lower power consumption. The guts include a 1.3 GHz AMD Athlon II dual-core processor, up to eight gigs of DDR3 memory, and up to four LFF SATA drive bays. None of that is all that amazing until you consider that the machine starts at only $329, including a one year warranty. For details, visit **www.hp.com/go/proliant**. ▲

## FREE DUPE REMOVER

If you have a tendency to download the same file more than once (and who doesn't) or for any other reason have filled your hard drive with duplicate files, the solution may be CloneSpy — a freebie available at **www.clonespy.com**. It's been around for a while, but the latest version (2.52) was released just a couple months ago. This isn't just a routine that looks for duplicate names; it actually detects duplicates regardless of their name, date, time stamp, and location, and it finds zero-length files, as well. Redundant files can be handled in various ways, including deleting them, moving them to a specific folder, generating a list of dupes without doing anything about them, etc. The program received a five-star review from a CNET reviewer who put it through its paces and verified that it is fast (the search took only 40 s) and easy to operate. CloneSpy works with Windows 98/Me/2000/XP/Vista/NT (sorry, no Mac OS version). ▲

## MEMORY FEATURES WATER COOLING

Okay, first visit **www.gotoquiz.com/how_germaphobic_are_you** and find out if you are a true germaphobe. If not, and if no one else uses your computer, you can skip to the next section. Otherwise, you'll be thrilled by Germ Genie, a product developed by the UK's Falcon Innovations and tested at the University of Hertfordshire's Biodet laboratory. The device senses movement on the keyboard and, after a user has finished, irradiates it with UV light so as to prevent the spread of infections among multiple users. This may seem a bit extreme, but a 2008 study showed that keyboards can sport bacteria levels that are five times higher than those of a toilet seat. The university's tests on E.Coli, Staphylococcus Aureus, and Bacillus Subtillis reveal that GG kills 99 percent of germs across most of the keyboard in just two minutes, and across the entire keyboard in 10 minutes, so it appears to be effective. They don't seem to be stocked in retail outlets yet, but you can get one at **www.falconinnovations.co.uk**. The unit is priced at £140.00 ($222.50 as of this writing). Now all you need is a device to do something about the cookie crumbs, Cheeto dust, and earwax. ▲

■ Germ Genie kills 99% of keyboard germs in two minutes.

# CIRCUITS AND DEVICES

## VINTAGE DESIGN, MODERN PERFORMANCE

■Yamaha's R-S700 receiver brings modern features to a classic design.

Many of us who lived through the dawn of high fidelity still have fond memories of stand-alone stereo components from Harman/Kardon, Marantz, Nakamichi, Acoustic Research, Crown, et. al. We're talking 25-lb monsters with power supplies that could heat a small cottage, a pitiful S/N ratio of maybe 50 dB, and a frequency range that barely made it up to 15 kHz. But that four foot tall stack of equipment sure looked impressive! As it turns out, Yamaha Electronics (**www.yamaha.com/yec**/) remembers, too, and they have a new line-up of receivers that resemble the dinosaurs of the 1970s and 1980s but offer modern features and "absolute sonic purity." At the top of the receiver line-up is the R-S700 which delivers 100 W/channel (8 ohms), THD of 0.015% to the speakers (20 Hz to 20 kHz, 50W), and a S/N ratio of 87 dB or more. It offers modern connectivity via an iPod dock connection, and you can hook up a Bluetooth wireless audio receiver or Sirius radio. One interesting feature is the CD Direct Amp. At the flip of a switch, the signal from a CD player is routed directly to a separate amplifier, bypassing the input selector and the bass, treble, balance, and loudness controls, thus eliminating any alterations to the CD signal and creating a purer sound. The bad news is that the MSRP is $549.95, but if Santa's on a budget this year, you can always scale back to the R-S500 (75 W/channel, $399.95) or the R-S300 (50 W/channel, $329.95). On the other hand, if you're a true classic audiophile who sneers at receivers in general, you can combine the A-S500 amplifier (85 W/channel, $449.95) with the T-S500 AM/FM stereo tuner ($299.95) and maintain your lofty standards. ▲

## READY TO SPLURGE?

■The Stuart Hughes Supreme Rose, billed as the world's most expensive iPhone.

If you just can't find that special gift for a special person, you might consider the iPhone 3GS Supreme Rose from the UK's Stuart Hughes (**www.stuarthughes.com**). Sure, it's just an iPhone inside, but it has a hand-made platinum bezel with 130 0.75 ct flawless diamonds. It also is set with four pink baguette diamonds, each of which weighs 2.5 ct. The rear section is formed with 112 g of 18 ct rose gold, and the Apple logo is affixed with 53 diamonds. The main navigation single-cut 7.1 ct diamond is set in 18 ct rose gold, and the handset is (legally) unlocked for worldwide use. Included is a hand-finished wallet made from a real ostrich foot. At the current exchange rate, you can drop one in someone's stocking for a mere $3,063,869.04. What? Out of your price range, you say? Well, you lousy cheapskate, you can get a simple 22 ct gold version for only $35,941.21, but don't expect the same level of excitement and gratitude. With either choice, try not to leave it in your shirt pocket when you're leaning over a handrail at Niagara Falls. ▲

# INDUSTRY AND THE PROFESSION

## SEGWAY SEGUE

■ For safe Segwaying, don't forget your wingsuit.

It's a tragedy, of course, but you can't help but marvel at the irony that James Heselden, owner of the company that builds Segways (**www.segway.com**), was found deceased after driving his scooter over a 30 ft drop into the River Wharfe near Boston Spa, 140 miles north of London. The 62 year old businessman bought control of the company just a year ago. Heselden made his fortune with his company, Hesco Bastion Ltd., which developed a system to replace sandbags for protecting troops. According to Tom Riordan, chief executive of the Leeds City Council, "Jimi was an amazing man who, apart from being a wonderful success story for Leeds due to his business acumen, was also remarkably selfless and generous, giving millions to local charities to help people in his home city." If only he had bought the Phoenix-Fly wingsuit company (**www.phoenix-fly.com**) as well ... **NV**

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USB · USB Stick · optional IEEE-488 · optional TCP/IP · DVI Output · inclusive

- ☑ **4 GSa/s Real time, 50 GSa/s Random sampling, low noise flash A/D converter (reference class)**
- ☑ **2 MPts memory per channel, memory Zoom up to 100,000:1**
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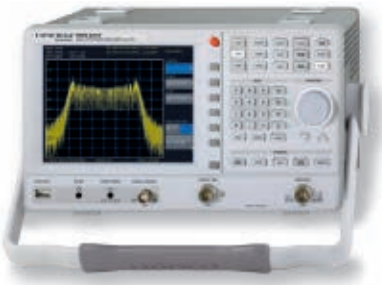
## 3 GHz Spectrum Analyzer HMS 3000/HMS 3010



1GHz: HMS1000 HMS1010

USB · USB Stick · optional IEEE-488 · optional TCP/IP · DVI Output · inclusive

- ☑ Frequency range 100 kHz...3 GHz
- ☑ Amplitude measurement range -114...+20 dBm
  DANL -135dBm with Preamp. Option HO3011
- ☑ Sweep time 20 ms...1000 s
- ☑ Resolution bandwidth 100 Hz...1 MHz in 1–3 steps, 200 kHz (-3 dB)
  additional 200 Hz, 9 kHz, 120 kHz, 1 MHz (-6 dB)
- ☑ Spectral purity < -100 dBc/Hz (@100 kHz)
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USB · RS-232 · optional IEEE-488 · optional TCP/IP · inclusive

- ☑ HMP2020: 1 x 0...32 V/0...10 A 1 x 0...5.5 V/0...5 A, max. 188 W
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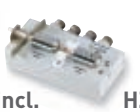
- ☑ Frequency range 10 µHz...25 MHz/50 MHz
- ☑ Output voltage 5 $mV_{pp}$...10 $V_{pp}$ (into 50 Ω) DC Offset ±5 mV...5 V
- ☑ Arbitrary waveform generator: 250 MSa/s, 14 Bit, 256 kPts
- ☑ Sine, Square, Pulse, Triangle, Ramp, Arbitrary
  waveforms incl. standard curves (white, pink noise etc.)
- ☑ Total harmonic distortion 0.04 % (f < 100 kHz)
- ☑ Burst, Sweep, Gating, external Trigger
- ☑ Rise time < 8 ns, in pulse mode 8...500 ns variable-edge-time
- ☑ Pulse mode: Frequency range 100 µHz...12.5 MHz/25 MHz,
  pulse width 10 ns...999 s, resolution 5 ns
- ☑ Modulation modes AM, FM, PM, PWM, FSK (int. and ext.)
- ☑ 10 MHz Timebase: ± 1ppm TCXO, rear I/O BNC connector
- ☑ Front USB connector: save & recall of set-ups and waveforms
- ☑ 3.5" TFT: crisp representation of the waveform and all parameters

## LCR-Bridge HM8118



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- ☑ Basic Accuracy 0.05 %
- ☑ Measurement functions L, C, R, |Z|, X, |Y|, G, B, D, Θ, Δ, D, M, N
- ☑ Test frequencies 20 Hz...200 kHz
- ☑ Up to 12 measurements per second
- ☑ Parallel and Series Mode
- ☑ Binning Interface HO118 (optional) for automatic sorting of components
- ☑ Internal programmable voltage and current bias
- ☑ Transformer parameter measurement
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## 1,2 GHz/3 GHz RF-Synthesizer HM8134-3/HM 8135

USB · RS-232 · optional IEEE-488

- ☑ Outstanding Frequency range 1 Hz...1,2 GHz/3 GHz
- ☑ Output power -127...+13 dBm/-135...+13 dBm
- ☑ Frequency resolution 1 Hz (accuracy 0.5 ppm)
- ☑ Input for external time base (10 MHz)
- ☑ Modulation modes: AM, FM, Pulse, Φ, FSK, PSK
- ☑ Rapid pulse modulation: typ. 200 ns
- ☑ Internal modulator (sine, square, triangle, sawtooth) 10 Hz...150 kHz/200 kHz
- ☑ High spectral purity
- ☑ Standard: TCXO (temperature stability: $\pm 0.5 \times 10^{-6}$)
  Optional: OCXO (temperature stability: $\pm 1 \times 10^{-8}$)
- ☑ Galvanically isolated USB/RS-232 Interface, optional IEEE-488
- ☑ 10 configuration memories including turn-on configuration


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# PICAXE PRIMER

SHARPENING YOUR TOOLS OF CREATIVITY

■ BY RON HACKETT

# INTRODUCTION TO THE PICAXE-18M2 PROCESSOR

**As promised, in this month's Primer we're going to take our first look at the new PICAXE-18M2 processor. If you read the brief "teaser" of new 18M2 features that I included in the previous installment, you already know that it's an impressive processor, to say the least. (If not, see Figure 1 which is reprinted from that installment.) Compared to the older 18M, the 18M2 has eight times the program memory, twice the number of general-purpose variables (b0 to b27), more than five times as many storage variables (that can be accessed via the peek and poke commands), and 256 bytes of EEPROM storage that aren't decreased by the size of the program. The 18M2 can also run up to four times faster than the 18M, and do so with voltages as low as 1.8 volts which means that battery-powered projects now only need a two AA-cell supply to function correctly.**

The 18M2 processor has a total of 16 I/O lines, and 13 of them are bi-directional which provides a considerable amount of flexibility for designing projects. In addition, up to 10 of the I/O lines can be configured as ADC inputs. Even better, the 18M2 is the first PICAXE processor to include internal capacitive touch-sensitive sensors. Any (or all) of the ADC inputs can be configured to automatically detect the touch of a human finger. All it takes is a small piece of metal as the sensor plate – no switches or other moving parts are required. In fact, the finger doesn't actually need to touch the metal, just come very close. This means that it will be easy to design custom touch-sensitive "key" pads, and then print a custom graphic layout on a self-adhesive sheet which will result in a very professional-looking project.

The 18M2 also sports a new digital-to-analog converter (DAC) output pin that is capable of producing 32 voltage levels that can easily be adjusted via software. In addition, there's a new internal hardware Set-Reset (SR) latch which is also under program control. One of its features sounds especially interesting; the latch's output pin can be configured to function like a 555 timer chip in the background.

| | 18M2 | 18M |
|---|---|---|
| Program Storage (bytes) | 2048 | 256 |
| General Purpose Vars (bytes) | 28 | 14 |
| Storage Variables (bytes) | 256 | 48 |
| EEPROM Storage (bytes) | 256 | 256-prog |
| Max Operating Speed (MHz) | 32 | 8 |
| Min Operating Voltage (V) | 1.8 | 3.0 |

■ FIGURE 1. Comparison of 18M2 vs. 18M selected features.

As I mentioned last time, the 18M2 also includes several new software enhancements. For example, there's a new built-in *time* variable that automatically keeps track of elapsed time (in seconds) in the background while your program is carrying out other tasks. This means that a project will be able to include a real-time clock feature without necessitating additional hardware or complicated software interrupt routines. The *time* variable is reset to 0 each time your program is run, but a new value can be assigned to it at any point during a program, so it can be manipulated as simply as any other variable in a program. Also, the 18M2 will be able to run up to four different program tasks in parallel at the same time by rapidly switching among the various program "threads." This new capability isn't multitasking in the strict sense, because program instructions are still being executed one at a time. However, the

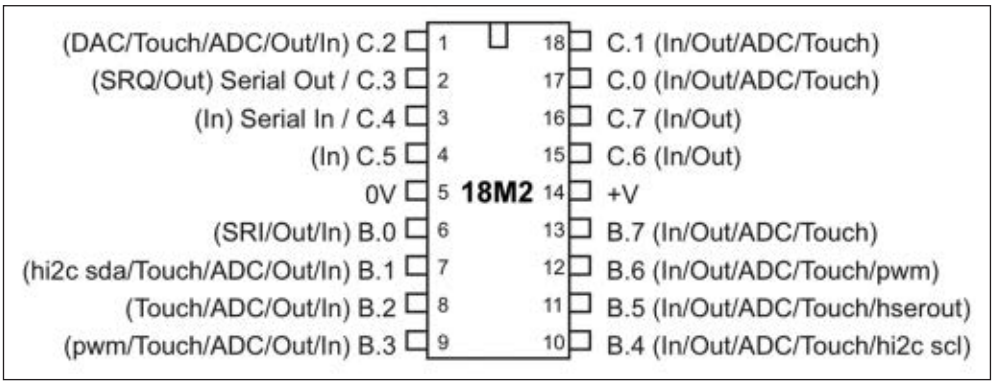
automatic switching among program threads will occur so rapidly that it will create the illusion of multitasking.

## EXPERIMENTING WITH THE 18M2 TOUCH SENSORS

We'll explore many of the 18M2's new hardware and software features in upcoming installments of the Primer. This month, we're going to start with what I consider to be the most exciting new feature: the capacitive touch-sensitive inputs. In order to do so, we'll conduct a series of simple experiments to familiarize ourselves with the capabilities and characteristics of the new touch inputs.

Before we get to our experiments, however, let's take a quick look at the 18M2 pin-out (see **Figure 2**). The first thing you may notice is that the locations of the *power*, *ground*, *sin*, and *sout* pins don't follow the pattern of the older M-class processors; the pin arrangement is much more in keeping with that of the 18X processor (which, along with the 18M, has been superceded by the 18X2). As a result, some care is necessary when setting up a basic 18M2 breadboard circuit, especially when connecting the + and – power pins. Secondly, the pin function that is closest to each pin name is that pin's default function. As you can see, almost all the pins default to general-purpose inputs – this is a safety feature that's designed to prevent outputs from being improperly initialized at startup. If you have worked with the 20X2 processor, you're already familiar with this concept.

Another 18M2 feature has been adopted from the X2 processors: the "*port dot pin*" naming convention; for example, the name *B.7* identifies that pin as *portB*, *pin7*. This same pin-naming convention will also be used on all the subsequent M2-class processors. As a result, the way that a program refers to a pin (e.g., *high B.7*) will be standardized across the entire line of PICAXE processors which greatly simplifies the process of writing programs for different processors.




■ FIGURE 2. 18M2 pin-out.

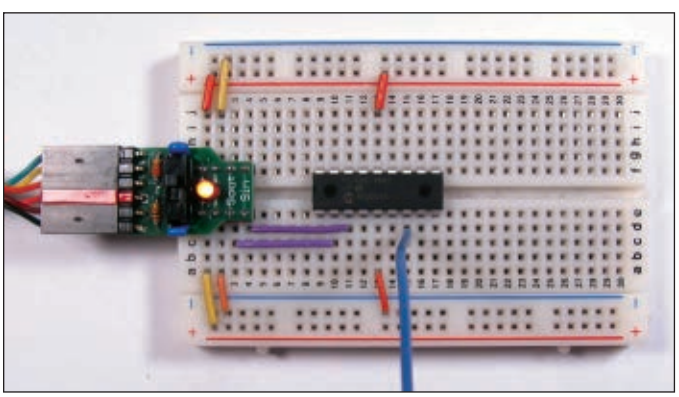
If you don't already have an 18M2 on hand, now would be a good time to order a couple. I ordered my first 18M2 processors directly from RevEd in England on the day that they were announced, and then I waited impatiently for 10 days or so to receive them in the mail. Fortunately, the 18M2 chips are now available here in the US from Peter Anderson (**www.phanderson.com/picaxe/index.html**), and shipping only takes about three or four days or so.

## EXPERIMENT 1: THE "I CAN'T WAIT!" EXPERIMENT

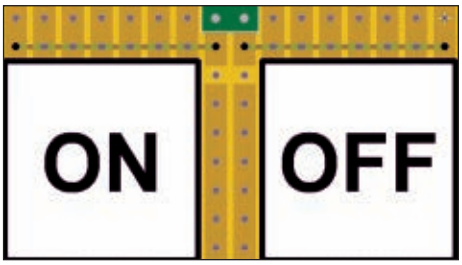
When I finally got my hands on the 18M2, the first thing I wanted to experiment with was the new touch-sensitive inputs. I was in such a hurry that I didn't even want to take the time to make a simple touch pad, so I just cut a six inch piece of jumper wire, stripped about 3/8" of the insulation from one end, and inserted it into a basic 18M2 breadboard circuit so that the wire connected with pin B.1 — which is one of the 18M2's 10 touch input pins. (You can see my sophisticated experimental setup in **Figure 3**.) The software for my first experiment is just as simple as the hardware:

```
; === TouchTest1.bas ===
; Tests a touch sensor.

; === Directives ===
  #com 5
  #picaxe 18M2
  #no_data
  #terminal 4800

; == Begin Main ===
do
  touch B.1, b1
  sertxd (#b1,cr,lf)
  pause 250
loop
```

As you can see, the *touch* command can be very simple, but you may also want to read the documentation in Section 2 of the PICAXE manual for some of the more complicated details. The complete syntax is: *touch channel, variable*. *Channel* is the pin that is being used as the touch input (pin B.1, in this case), and *variable* is the variable that receives the byte value of the touch reading (variable b1, in this case). Of course, I could also have defined meaningful names for both of the



■ FIGURE 3. Breadboard setup for Experiment 1.




■ FIGURE 4. Stripboard layout for a simple two-key touchpad.

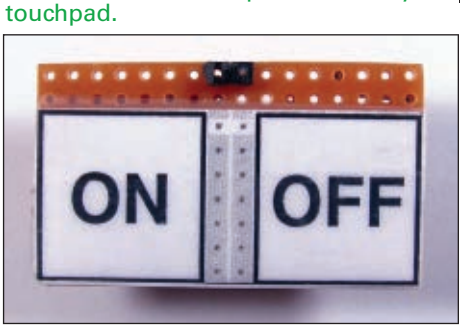
parameters, but I was in too much of a hurry! When I ran the program without touching the jumper wire, the value of variable b1 that was displayed in the Terminal Window ranged between 13 and 15; as soon as I touched the wire (actually, the insulation – more about that shortly), the value of b1 jumped to 50 or more. In fact, if I squeezed the insulation between two fingers, I could easily raise the value above 200. However, it's not the pressure of the "squeeze" that it being sensed; it's the greater surface area of the two squeezing fingers that come in close proximity to the wire.

Before you actually begin your own experiments, I want to mention an important aspect of using the touch sensors on the 18M2, or any of the other M2 processors that will be released in the future. The term "touch sensor" is actually a bit of a misnomer, in that the sensor itself (in this case, the jumper wire) is never actually touched. In fact, the documentation in Section 2 of the manual includes the following, somewhat ominous warning: "Never 'directly touch' a touch sensor (e.g., a piece of bare wire)! A touch sensor must be electrically isolated from the end user." So, "proximity sensor" might be a more apt term for what's involved, but don't forget that PICAXE processors are used throughout the British public school system which may explain the choice of terminology. In any case, it's easy to confirm that proximity is what's being measured. When my little test program is running, if I place my finger close to the insulation on the jumper wire, I can easily increase the value of b1 to 30 or more without actually touching the insulation.

So, as soon as you can get your hands on an 18M2, set up our little test circuit on a breadboard. The circuit is so simple that you don't even need a schematic, just use the photo shown in **Figure 3**.

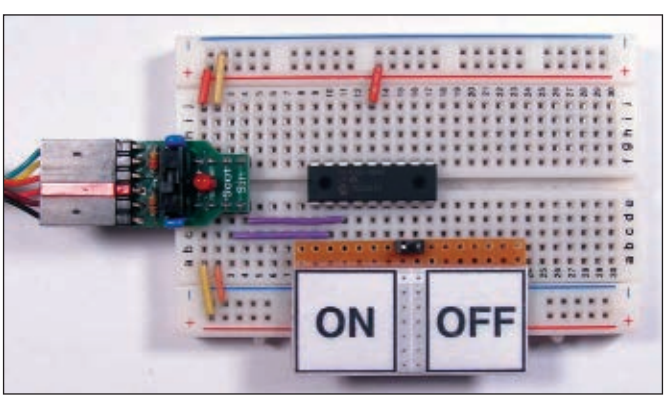
Next, use the Programming Editor (or AXEpad) to type in *TouchTest1.bas* and download it to your 18M2 circuit. See how your results compare with mine, and what other interesting findings you can discover.

■ FIGURE 5. The completed two-key touchpad.




## EXPERIMENT 2: CONSTRUCTING AND TESTING A "PROPER" TOUCHPAD

After playing with (oops – I meant to say experimenting with) my jumper wire sensor, I decided to construct a simple touch pad. Naturally, I used a small piece of stripboard, and to keep things simple I limited myself to just two "keys" for my first attempt. The stripboard layout that I used is presented in **Figure 4**. I haven't included a bottom view because the only two cuts that need to be made on the bottom of the board are clearly visible in **Figure 4**. (Their function is to simply create a dead zone between the two keys.) The two-pin male header at the top of the stripboard is reverse-mounted so that the keypad can be directly inserted into a breadboard, connecting the two keys to two adjacent touch inputs on the 18M2. The two bare wire jumpers on the bottom of the board each connect seven adjacent traces to one of the two header pins. To solder each jumper to the bottom of the board, just hold it in place with a small spring clamp, solder it to three or four traces, and then remove the clamp and solder it to each of the remaining traces spanned by the jumper.




■ FIGURE 6. Breadboard setup for Experiment 2.

**Figure 5** is a photo of the completed keypad, and **Figure 6** shows it inserted into the same breadboard circuit we just used for our jumper wire. The two pins of the keypad are inserted next to pins B.1 and B.2 of the 18M2 — both of which are touch inputs. I made the paper label on top of the keypad by printing out the stripboard layout in actual size, and trimming it to fit. Before I taped the paper label to the top of the stripboard (using cellophane tape), I covered the bottom of the board with a piece of electrical tape to be sure the board didn't make electrical contact with any jumpers that might be located beneath it on a breadboard project. The process was simple, and it makes it clear that it will also be easy to create multi-colored graphic labels for a couple of the larger keypads that I already have in mind.

In order to test our new keypad, we only need to make two minor modifications to the *TouchTest1.bas* program that we just used:

**1**) Right after the *touch B.1, b1*

statement, add a *touch B.2, b2* statement.

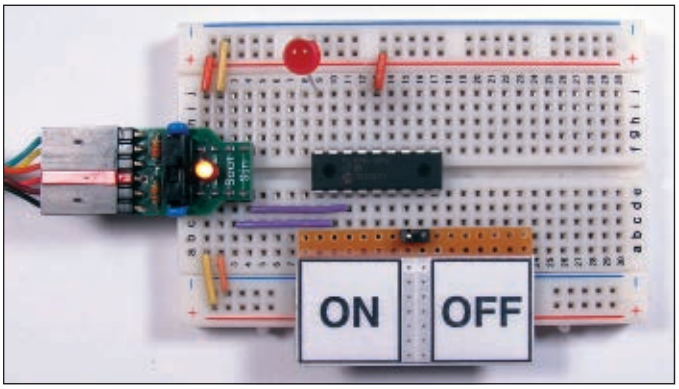
**2**) Edit the *sertxd* statement so that it reads *sertxd (#b1, 32, #b2, cr, lf)* (32 is the ASCII code for a space; it just separates the two values).

After I saved my edited program with a new name (*TouchTest2.bas*), I ran it and conducted a few more experiments. Before I describe some of my results, I want to mention three additional aspects of working with the 18M2's touch sensors that are important to keep in mind. First, analogously to the *readADC* and *readADC10* commands, there are actually two different touch related commands (*touch* and *touch16*). We're not going to discuss the details of the *touch16* command this time, but it would be a good idea to familiarize yourself with the differences between the two commands. Secondly, as mentioned in Section 2 of the manual, each of the 10 touch-sensitive inputs on the 18M2 will produce slightly different readings from the same touch pad. In other words, if we were to move our two-key keypad to two different touch-sensitive inputs on the 18M2, the touch readings that I'm about to discuss would be somewhat different.

Also, changes in various characteristics of the hardware that you are using will also have an impact on the touch readings. For example, if you change the size of a touchpad or the length of the wire leading to it, the reading will change when the pad is touched. Finally, how lightly or heavily the sensor is touched also changes the touch reading. I think this variation is produced by the fact that pressing a touch sensor firmly as opposed to lightly results in a larger area of skin coming as close to the surface of the sensor as possible.

Keeping the above considerations in mind, let's take a look at the results that I obtained when I first tested my two-key touch keypad. When I ran *TouchTest2.bas* without touching either key, my "On" key (pin B.1) produced a touch reading that varied from 90 to 92, while my "Off" key (pin B.2) reading varied between 82 and 84. By positioning my finger very close to either key (without actually touching the paper label), I could easily increase each of these readings by a value of 25 or more. Lightly touching the on key produced a value of about 160 ± 10 or so; lightly touching the off key resulted in readings of 170 ± 10. A medium amount of pressure produced readings in the vicinity of 200 for both pins; pressing very firmly on either key produced readings greater than 220.

■ FIGURE 7. Breadboard setup for Experiment 3.




At one point, I accidentally hit a small plastic tube on my desk, moving it close to my keypad. Even this small change in the keypad's environment affected the results; the non-touch readings decreased by approximately a value of 10. Finally, I also found a small variability in my results when I repeated my tests on a couple of different days; I think this was due to changes in temperature and/or humidity.

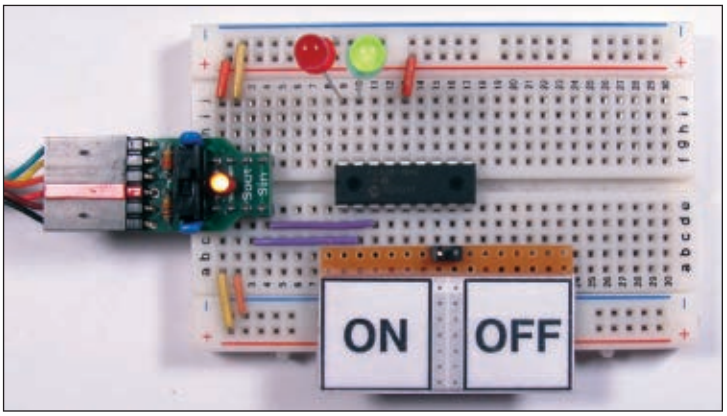
My main purpose in discussing some of the details of my results is to emphasize the fact that the touch readings have a considerable amount of variability which can be produced by a variety of environmental factors. These factors need to be taken into consideration when designing both the hardware and software aspects of a project that involves touch sensors. When you implement your touch keypad and run the *TouchTest2.bas* software, see how closely your results parallel mine. If you discover additional factors that also influence the variability of your touch readings, send me an email (Ron@JRHackett.net) describing your findings and I'll mention them in a future Primer.

## EXPERIMENT 3: IMPLEMENTING A SINGLE MOMENTARY TOUCH-SENSITIVE KEY

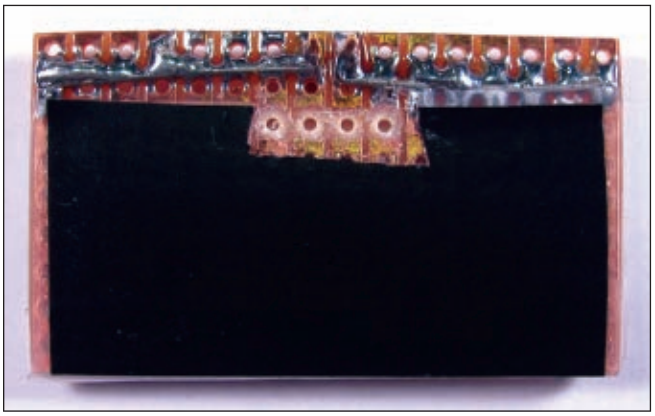
Now that we have experimented with some of the factors that influence the touch readings, let's turn our attention to implementing a single momentary touch-sensitive key. For this experiment, our hardware remains the same, except for the addition of a red LED on pin C.1 (see **Figure 7**). As usual, I'm using a resistorized LED, but don't forget to include the current-limiting resistor if you use a non-resistorized LED. The program for our next experiment is again simple enough to directly type into the Programming Editor:

```
; === TouchMoment.bas ===
; Implements a single
; momentary touch "key"

; === Constants ===
  symbol LED_R = C.1
  symbol onKey = B.1

; === Variables ===
  symbol onVal = b1

; === Directives ===
  #com 5
  #picaxe 18M2
  #no_data
  #terminal off

; === Begin Main ====
do
  touch onKey, onVal
  if onVal > 100 then
    high LED_R
  else
    low  LED_R
  endif
loop
```

worldmags




■ FIGURE 8. Breadboard setup for Experiment 4.



■ FIGURE 9. Bottom view of modified touchpad.

Download *TouchMoment.bas* to your breadboard setup. Whenever you touch the on key, the red LED should light; as soon as you withdraw your finger, it should go out. When the circuit is functioning correctly, try sliding your finger back and forth between the on key and the off key, and watch the LED as you do so. You will most likely find that you need to slide your finger entirely off the on key before the LED goes out. In fact, you may even be able to light the LED before your finger is actually touching the on key at all.

Next, change the value in the *if...then* statement to 150 and slide your finger back and forth on the keypad again to see the difference it makes. This little experiment should highlight the importance of properly calibrating any touchpad sensors you implement in a project. (Also, don't forget that each pin may require a slightly different calibration.)

## EXPERIMENT 4: IMPLEMENTING TWO LATCHED TOUCH-SENSITIVE KEYS

For our last experiment, we're going to modify the previous experiment so that it implements two latching keys. In order to do so, just add a green LED (and a current-limiting resistor if necessary) to pin C.0 on your breadboard setup (see **Figure 8**) and modify the *TouchMoment.bas* program by adding two additional constant definitions (*LED_G = C.0* and *offKey = B.2*), one additional variable definition (*offVal = b0*), and editing the main *do...loop* so that it reads as follows:

```
do
  touch onKey, onVal
  touch offKey, offVal

  if onVal > 100 then
    high LED_R
    low  LED_G
  endif

  if offVal > 100 then
    low  LED_R
    high LED_G
  endif
loop
```

Save the modified program as *TouchOnOff.bas*, download it to your breadboard setup, and test it out. You may also want to experiment with adjusting the calibration values in the two *if...then* statements to see what happens. For example, suppose the two switches were controlling a device for which an accidental on condition would be much more serious than an accidental off condition. How would you want to calibrate the two switches in that situation? Also, what changes would you make if the reverse were true, i.e., an accidental off condition had serious consequences?

## EXPERIMENT 5: MODIFYING THE TOUCH KEYPAD

Even after I did a fair amount of

experimenting with changing the calibration values in *TouchOnOff.bas*, I still thought the keypad was a little too sensitive, so I decided to do one more experiment. This time, I modified the keypad itself by increasing the dead zone between the two keys. First, I used a hobby knife to remove a small piece of electrical tape from the bottom of the keypad as shown in **Figure 9**. Next, I severed one more trace on either side of the two traces that were already severed. After I took the photo in **Figure 9**, I added a small piece of electrical tape to cover the area that I had modified.

In effect, this procedure reduced the size of each key by one trace, and increased the dead zone distance between the two keys from two to four traces. Of course, I also could have made a second keypad with a larger dead zone between the keys, but it was a lot easier to just modify the one I already had.

Naturally, I had to recalibrate the keypad because each key had become smaller. After doing so and re-testing the keypad, I thought its functioning was greatly improved; I was much less likely to incorrectly change the state of the LED by a somewhat off-center tap on either key. Of course, if you read this entire article before you construct your keypad, you could just make it larger in the first place. However, I would recommend you take the same approach that I did; being able to experiment with both versions of the same keypad was very instructive.

## TO BE CONTINUED ...

That's it for this month. Next time, we'll continue our experiments with the 18M2 by implementing a touch-sensitive matrix keypad. I'm sure it will come as no surprise that a stripboard or two will be involved in its creation. I also have been doing some preliminary experimentation with ways of using the 18M2's touch sensors to detect the presence of water or other liquids and/or to measure the level of a fluid in a non-metallic tank.

In case you are wondering why I would be interested in that application, it's because I use an espresso machine that doesn't allow me to see the water level in the tank without partially disassembling it. If the tank accidentally runs dry, considerable damage can be done to the machine, so an inexpensive water-sensing device would be a great safety feature to add to the machine.

I also intend to cover some of the other new 18M2 features in upcoming columns. If you are especially interested in me taking a look at a specific feature, send me an email and let me know. See you next time ... **NV**

# Get Ready For The Holidays With a Ramsey Kit!

## Digital Controlled FM Stereo Transmitters

- ✔ **PLL synthesized for drift free operation**
- ✔ **Front panel digital control and display of all set tings and parameters!**
- ✔ **Professional metal case for noise-free operation**
- ✔ **EMI filtering on audio and power inputs**
- ✔ **Super audio quality, rivals commercial broadcasts**
- ✔ **Available in domestic kit or factory assembled export versions**

For nearly a decade we've been the leader in hobbyist FM radio transmitters. We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!

The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version with 1W output for our export only market!

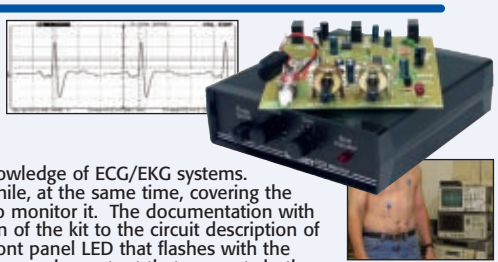
All settings can be changed without taking the cover off! Enter the setup mode from the front panel and step through the menu to make all of your adjustments. A two line LCD display shows you all the settings! In addition to the LCD display, a front panel LED indicates PLL lock so you know you are transmitting.

Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level. In addition to settings, the LCD display shows you "Quality of Signal" to help you set your levels for optimum sound quality. And of course, all settings are stored in non-volatile memory for future use! Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)*

**FM30B** Digital FM Stereo Transmitter Kit, 0-25mW, Black **$199.95**
**FM35BWT** Digital FM Stereo Transmitter, Assembled, 0-1W, Black (Export ONLY) **$299.95**

## Electrocardiogram ECG Heart Monitor

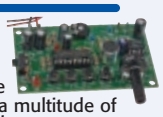
- ✔ **Visible and audible display of your heart rhythm!**
- ✔ **Bright LED "Beat" indicator for easy viewing!**
- ✔ **Re-usable hospital grade sensors included!**
- ✔ **Monitor output for professional scope display**
- ✔ **Simple and safe 9V battery operation**



Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition, a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on ER... or in the ER! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Safe 9V battery operation.

**ECG1C** Electrocardiogram Heart Monitor Kit With Case & Patches **$44.95**
**ECG1WT** Electrocardiogram Heart Monitor, Factory Assembled & Tested **$89.95**
**ECGP10** Electrocardiogram Re-Usable Probe Patches, 10-Pack **$7.95**

## Digital Voice Changer



This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.

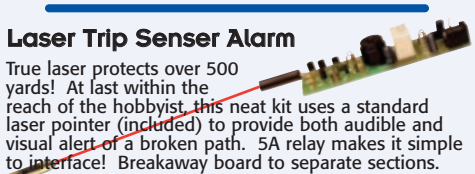
**MK171** Voice Changer Kit **$14.95**

## Steam Engine & Whistle

Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.

**MK134** Steam Engine & Whistle Kit **$11.95**

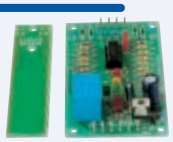
## Laser Trip Senser Alarm



True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

**LTS1** Laser Trip Sensor Alarm Kit **$29.95**

## Liquid Level Controller



Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.

**K2639** Liquid Level Controller Kit **$23.95**

# The Holiday Spotlight!

## LED Animated Santa

This animated Santa and reindeer display has been our most popular holiday display for years! It contains a whopping 126 dazzling colored LEDs which make it a great holiday sign that is guaranteed to draw attention!

LED animated motion makes it come alive. Runs on standard 9V battery or 9-12VDC external power supply. Dazzle your friends this great display!

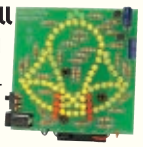
**MK116** LED Animated Santa Kit **$16.95**

## LED Christmas Tree

Electronic Christmas tree features 134 bright colored LEDs in the shape of a gorgeous holiday Christmas tree. Includes 18 random flashing blinking "candles" on the PC board! Runs on a 9V battery or external 9-12VDC power supply.

**MK117** LED Christmas Tree Kit **$18.95**

## LED Animated Holiday Bell



This PC board holiday bell is animated to simulate a bell swinging back and forth! 84 bright colored LEDs will dazzle you with holiday cheer! Includes an on/off switch. Runs on 9V.

**MK122** LED Animated Bell Kit **$16.95**

## 3D LED Christmas Tree

Not your average LED display! 4 branch sections give this tree a true 3D look! 16 red LEDs light it up with yellow LED's for you to customize your tree! The base of the tree is actually the 9V battery acting as a self supporting base! Now that's pretty neat!

**MK130** 3D LED Christmas Tree Kit **$7.95**

## SMT LED Christmas Tree

Build this subminiature Christmas tree and learn SMT at the same time. Small enough to wear as a badge or pendant! Extra SMT parts are included so you can't go wrong! Runs on Li-Ion cell.

**MK142** SMT LED Christmas Tree Kit **$10.95**

## SMT LED Smiley Face

This is a great attention grabber and also teaches you the basics of SMT construction! Perfect to wear through the holiday season or to hang on your tree as an attention getting ornament! ! Extra parts included! Runs on Li-Ion cell.

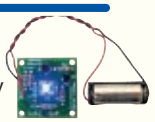
**MK141** SMT LED Smiley Kit Kit **$9.95**

## LED Traffic Signal

Not exactly a holiday theme, a real attention getter for this time of the season! Impress your friends with this neat 4-way traffic signal! Operates just like a standard signal, and features adjustable delay. Red, yellow, and green LEDs are used just like the real thing! Runs on 9V battery.

**MK131** LED Traffic Signal Kit **$7.95**

## LED Switcher Blinkey



Wait, an LED that runs on 3VDC running on 1.5VDC? Learn power supply switching and end up with a super bright Telux LED blinking at 140 kHz! Great to light up your ornaments! Runs on a single standard AA battery (not included).

**LSW1** LED Switcher Blinkey Kit **$14.95**

## Vintage Battery Eliminator

Collectors come across some great deals on antique battery-powered radios, but how to power them is a real problem. Many classic radios operated on batteries only, and in many cases a series of three batteries for each radio were required!

NEW!

The new ABCE1 Battery Eliminator gives you an easy way to replace all these batteries with a simple household AC power connection and resurrect your vintage antique radios! Provides "A" filiment, "B" plate, and "C" control grid supplies, which are all isolated from each other. Complete with aluminum case. Runs on 110-240VAC.

**ABCE1** **Vintage Radio Battery Elim Kit** **$199.95**

## Digital Message System

The third generation of Ramsey digital voice storage kits! We started with the latest digital voice storage technology. It provides up to 8 minutes of digital storage at a frequency response up to 3.5 KHz. (Total message time and frequency response is dependant on selected internal sampling rate.) Once recorded, messages are available for playback on-demand or automatic continuous looping. Standard RCA unbalanced line level output is provided for easy connection to any amplifier, amplified speaker, mixer, or sound system. In addition, a standard 4-8 ohm speaker output is provided to directly drive a monitor speaker. Can be remote controlled via 3-wire BCD with our interface options. Check www.ramseykits.com for all options!

**DVMS8** **Digital Voice Message 8Ch Kit** **$99.95**
**DVMS8WT** **Assembled DVMS8** **$149.95**

## Passive Aircraft Monitor

PATENTED!

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

**ABM1** **Passive Aircraft Receiver Kit** **$89.95**

## Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

**VS1** **Voice Switch Kit** **$9.95**

## RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

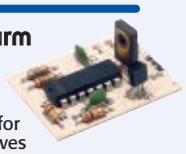
**SA7** **RF Preamp Kit** **$19.95**

## Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

**TS1** **Touch Switch Kit** **$9.95**

## *Mad Blaster* Warble Alarm



If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

**MB1** **Mad Blaster Warble Alarm Kit** **$9.95**

## Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

**LLS1** **Laser Light Show Kit** **$49.95**

## Water Sensor Alarm

This little $7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

**MK108** **Water Sensor Alarm Kit** **$6.95**

## USB DMX Interface

Control DMX fixtures with your PC via USB! Controls up to 512 DMX channels each with 256 different levels! Uses standard XLR cables. Multiple fixtures can be simply daisy chained. Includes Light Player software for easy control. Runs on USB or 9V power.

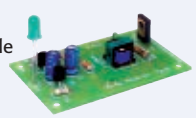
**K8062** **USB DMX Interface Controller Kit** **$67.95**

## Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

**IG7** **Ion Generator Kit** **$64.95**

## Tickle-Stick Shocker



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

**TS4** **Tickle Stick Kit** **$12.95**

## Tri-Field Meter Kit

THE GHOST DETECTOR!

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

**TFM3C** **Tri-Field Meter Kit** **$74.95**

## Electronic Watch Dog

A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike my Saint, eats 2-8VAC or 9-12VDC, it's not fussy!

**K2655** **Electronic Watch Dog Kit** **$39.95**

## Electret Condenser Mic

This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

**MC1** **Mini Electret Condenser Mic Kit** **$3.95**

## *Sniff-It* RF Detector Probe

Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

**RF1** **Sniff-It RF Detector Probe Kit** **$27.95**

## The Learning Center!

### Beginners To Advanced... *It's Fun!*

- ✔ **Learn and build!**
- ✔ **130, 200, 300, & 500 in one electronic labs!**
- ✔ **Practical through hole and SMT soldering labs!**
- ✔ **Integrated circuit AM/FM radio lab!**
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- ✔ **Beginner's non-soldering kits!**

For over 3 decades we've become famous for making electronics fun, while at the same time making it a great learning experience. As technology has changed over these years, we have continued that goal!

***PL130A*** Gives you 130 different electronic projects together with a comprehensive learning manual describing the theory behind all the projects.

***PL200*** Includes 200 very creative fun projects and includes a neat interactive front panel with 2 controls, speaker, LED display and a meter.

**PL300** Jump up to 300 separate projects that start walking you through the learning phase of digital electronics.

***PL500*** The ultimate electronics lab that includes 500 separate projects that cover it all, from the basics all the way to digital programming.

***SP3B*** Whether young or old, there's always a need to hone your soldering skills. Either learn from scratch or consider it a refresher, and end up with a neat little project when you're done!

***SM200K*** Move up to Surface Mount Technology (SMT) soldering, and learn exactly how to solder those tiny little components to a board!

***AMFM108K*** We not only take you through AM and FM radio theory but we guide you through IC's. When you're done you've built yourself an IC based AM/FM radio that works great!

***KNS10*** With a reversible PEM fuel cell that combines electrolysis and power conversion into a single device you end up building your own fuel cell car! Learn tomorrows technology today!

***KNS11*** Learn alternative fuel technology while you build your own H-Racer car and refueling station!

***KNS13*** Convert ethanol alcohol to run a PEM fuel cell and watch it all work in front of your eyes!

***KNS1*** A great beginner's kit for the dinosaur enthusiast in the family, young and old! A wooden hobby kit that teaches motor and gear driven operation that requires no soldering.

| | | |
|---|---|---|
| **PL130A** | **130-In-One Lab Kit** | **$39.95** |
| **PL200** | **200-In-One Lab Kit** | **$69.95** |
| **PL300** | **300-In-One Lab Kit** | **$89.95** |
| **PL500** | **500-In-One Lab Kit** | **$219.95** |
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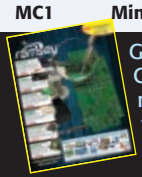

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# Q&A

## WHAT'S UP:

**Join us as we delve into the basics of electronics as applied to every day problems, like:**

- ✓ **Lightning Protection Circuit**
- ✓ **Fan Control**
- ✓ **Op-Amp Tester**

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to: Q&A@nutsvolts.com**

## PREAMP MODIFICATION

**Q** A lot of us still have big (size) sound systems at home. However, most of the turntables for vinyl records may have become obsolete but the integrated amplifiers still have an input (PHONO) which I think might be converted for other inputs. Other than changing the RCA jacks to 6.5 mm microphone jacks, can you kindly suggest any modifications in the electronic circuit that are deemed necessary? I am thinking of using 600 ohms unbalanced dynamic (coil) microphones so that I can utilize the set as a sort of PA system.

**— Francis Wan**

**A** The preamp has RIAA compensation which attenuates the high frequencies. I don't think that will be a problem for voice; I would make the jack change as you suggest and see how it sounds. Otherwise, you will need to remove the compensation network from the preamp which is not an easy job without a schematic and parts placement guide. Your amplifier no doubt has tone controls; just turn down the bass and turn up the treble. It should sound fine.

## OP-AMP TESTER FOR LM3900

**Q** I need an op-amp checker similar to the one in *Poptronics*, Nov. 2001, P43, *Op-Amp and Comparator Checker* by Charles Hansen.

I built the unit as shown, but I was unable to wire a socket to test an LM3900 (Norton current feedback op-amp).

**— Russ Proesel**

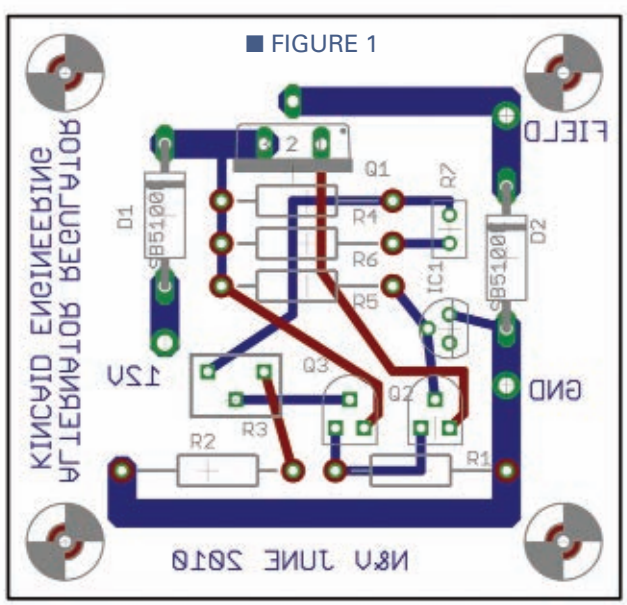
**A** I believe that all you need to do to make the LM3900 work in that tester is to connect a 1 meg resistor from the positive input to VCC and use the negative input for the signal.

Your question brought to mind an application for a microprocessor to do the job with one socket. I haven't worked out the details, but any op-amp that works on +5V and GND could be tested. An op-amp that requires a negative supply would need a separate socket.

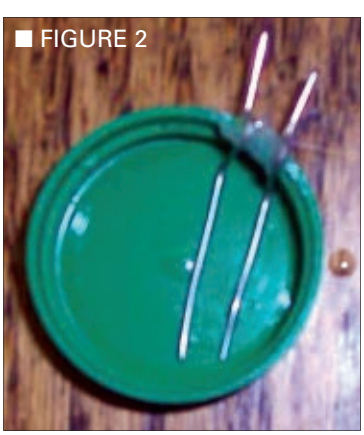
## VOLTAGE REGULATOR LAYOUT

**Q** Do you know of anyone that has or will make a printed circuit board circuit for the voltage regulator you designed in the June issue, page 22 of *Nuts & Volts*? I have not contacted Far Circuits because I don't know if they will do this since it is not a big circuit. I tried to make my own circuit, but the only resist pens have too fine a point to be of any use. Thanks for

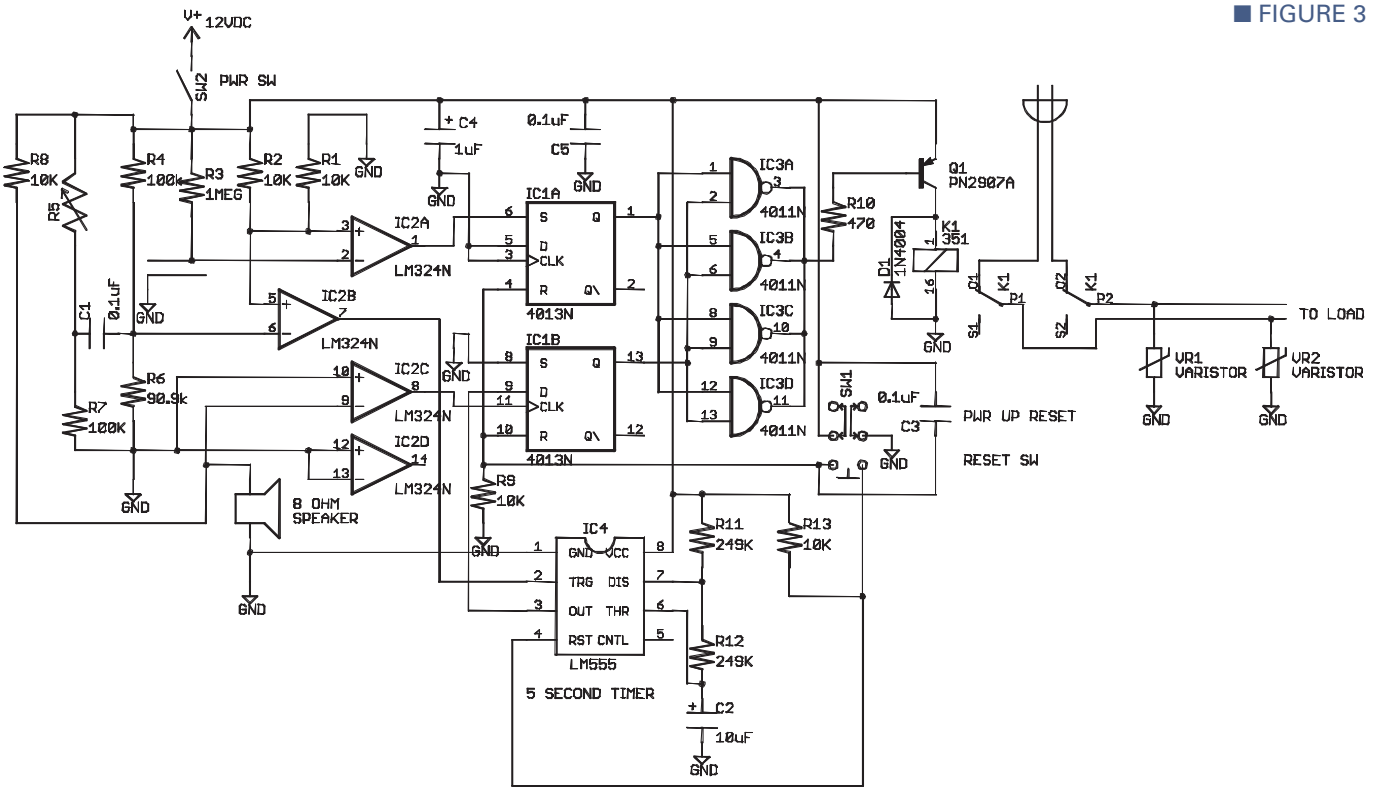
■ FIGURE 1




■ FIGURE 2



■ FIGURE 3




any help or suggestions.

**— Marvin**

A I have made a layout; see **Figure 1**. I plan to post the mirrored bottom layer on the *N & V* website so anyone can download it. Just load the .bmp file into Paint and print it. It will come out the right size so you can make a laser copy and iron it onto your copper clad. You will need to add some wires because I only made it single-sided. The parts placement guide (layout) is a separate file.

## LIGHTNING PROTECTION CIRCUIT

Q I have recently become fascinated with PIC microcontrollers and their capabilities. I was wondering if a PIC circuit can be made to (1) detect the rain; (2) detect the flash of lightning; and (3) determine the distance of the storm by the time delay of the sound of thunder.

The circuit would turn off any electrical device via a solid-state relay when the storm was imminently close. I was thinking of using a microphone, photo detector, and some type of moisture sensor. The PIC would have to calculate the fact that it is raining, then "see" the lightning flash and "hear" the thunder. These would all be ANDED together.

I usually unplug all my expensive equipment during a lightning storm, but if I'm not home my stuff is cooked! I thought this would be a neat project.

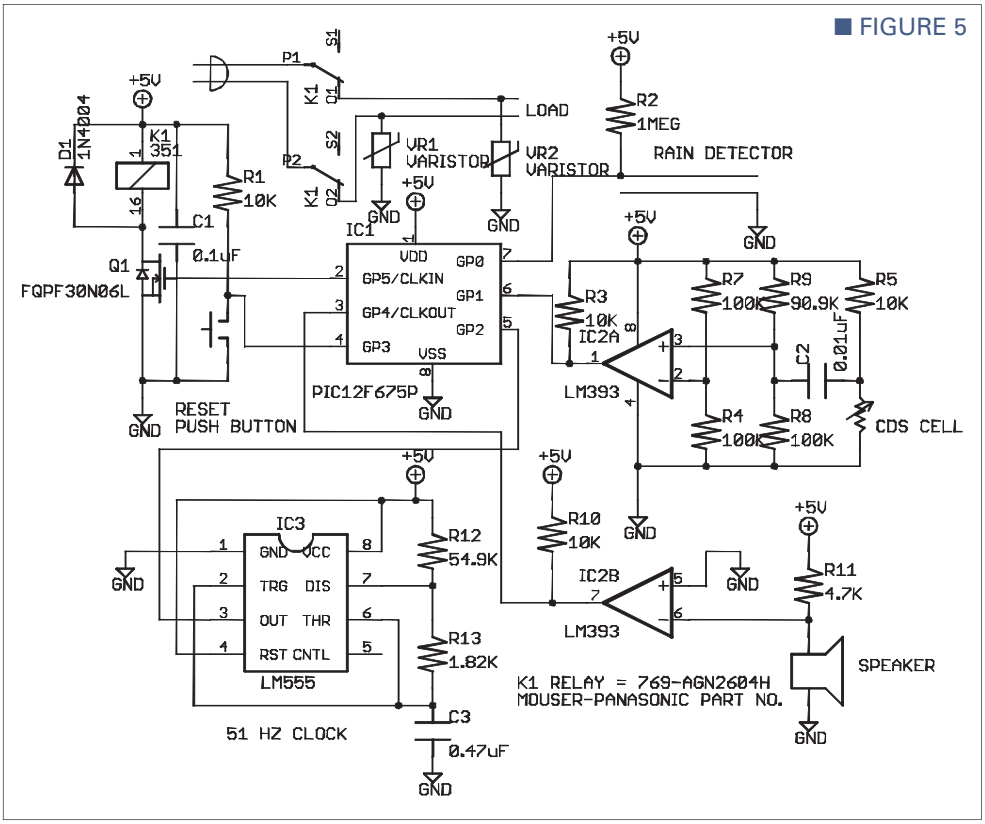
**— Fernando Cordero**

### LIGHTNING DETECTOR PARTS LIST

■ FIGURE 4

| PART | DESCRIPTION | PART # | COST |
|---|---|---|---|
| R1, R2, R9, R13, R8 | 10K, 1%, 1/4W | 271-10K-RC | 0.09 |
| R3 | 1 MEG, 1%, 1/4W | 271-1.0M-RC | 0.09 |
| R4, R7 | 100K, 1%, 1/4W | 271-100K-RC | 0.09 |
| R5 | RADIOSHACK CDS CELL | 276-1657 (5 pack) | 2.99 |
| R6 | 90.9K, 1%, 1/4W | 271-90.9K-RC | 0.09 |
| R10 | 470 OHMS, 1%, 1/4W | 271-470-RC | 0.09 |
| R11, R12 | 249K, 1%, 1/4W | 271-249K-RC | 0.09 |
| C1, C3, C5 | 0.1 µF, 10%, X7R | 81-RPER71H104K2P1A03 | 0.12 |
| C2 | 10 µF, 16V, 10%, TANTALUM | 74-199D16V10 | 0.65 |
| C4 | 1 µF, 35V, 10%, TANTALUM | 74-199D35V1.0 | 0.40 |
| IC1 | DUAL D FLIP-FLOP, CD4013 | 595-CD4013BEE4 | 0.50 |
| IC2 | QUAD OP-AMP, LM324 | 511-LM324N | 0.43 |
| IC3 | QUAD TWO-INPUT NAND, CD4011 | 595-CD4011BEE4 | 0.50 |
| IC4 | TIMER, LM/NE555 | 512-LM555CN | 0.31 |
| SW1 | MOMENTARY PUSHBUTTON DPDT, GOLD CONTACT | 633-MB246109-RO | 7.95 |
| SW2 | POWER SWITCH, SPST, TOGGLE | 108-1MS2T1B1M1QE-EVX | 1.90 |
| K1 | RELAY, DPDT, 12V | 653-G2R-2S-DC12S | 4.34 |
| SOCKET FOR RELAY | | 653-P2R-08P | 1.78 |
| D1 | GP DIODE, 1N4004 | 512-1N4004 | 0.07 |
| Q1 | PNP GP TRANSISTOR, PN2907 | 833-PN2907A-AP | 0.14 |
| VR1, VR2 | MOV TRANSIENT PROTECTOR 140 VRMS, 1,600 AMPS | 650-ROV20-221K-S-2 | 0.62 |

MOUSER PART NUMBERS (EXCEPT RADIOSHACK)




■ FIGURE 5

```
'****************************************
'*  Name    : lightning detector.BAS    *
'*  Author  : Russ Kincaid              *
'*  Notice  :                           *
'*  Date    : 9/8/2010                  *
'*  Version : 1.0                       *
'*  Notes   :                           *
'*          :                           *
'****************************************
    REM CONFIGURATION: INTERNAL OSC-CLK OUT,
    REM WDT DISABLED, PWR UP ENABLED, MCLR
    REM INPUT PIN,BROWN OUT DISABLED, NO PROTECTION
  CMCON = 7          'SET DIGITAL MODE
  ANSEL = 0          'TURN OFF ANALOG MODE
  TRISIO = %00011111     'GP.5 OUTPUT
  REM 12F675 HAS SIX I/O PINS, GP.0-GP.4
  REM ARE SET AS INPUT,GP5 IS OUTPUT
  REM GP2 IS DESIGNATED TMR0 CLOCK INPUT
  REM GP3 IS DESIGNATED RESET INPUT
  DEFINE OSCCAL_1K 1         'TO SAVE OSC CAL

    LOW gpio.5           'initial condition
    rain:        'look for rain
        IF gpio.0 = 0 THEN look
        GOTO rain

    look:        'look for lightning
        IF gpio.1 = 0 THEN setup
        GOTO look

    setup:
        INTCON = %10100000   'define interrupts
        option_reg = 232     'set TMR0 parameters
        TMR0 = 0             'initialize TMR0

    listen:      'listen for thunder
        IF gpio.4 = 1 AND INTCON.2 = 0 THEN pullplug
        REM if thunder occurs in less than 5 seconds
        IF INTCON.2 =1 THEN look
        REM if TMR0 overflowed (counted more than 5 sec)
        GOTO listen

    pullplug:
        HIGH gpio.5       'switch power off
         STOP
    END
```

■ FIGURE 6

a microphone to detect the thunder but I used a six inch speaker salvaged from a radio. The bias on the speaker is just to insure that the op-amp output is low normally.

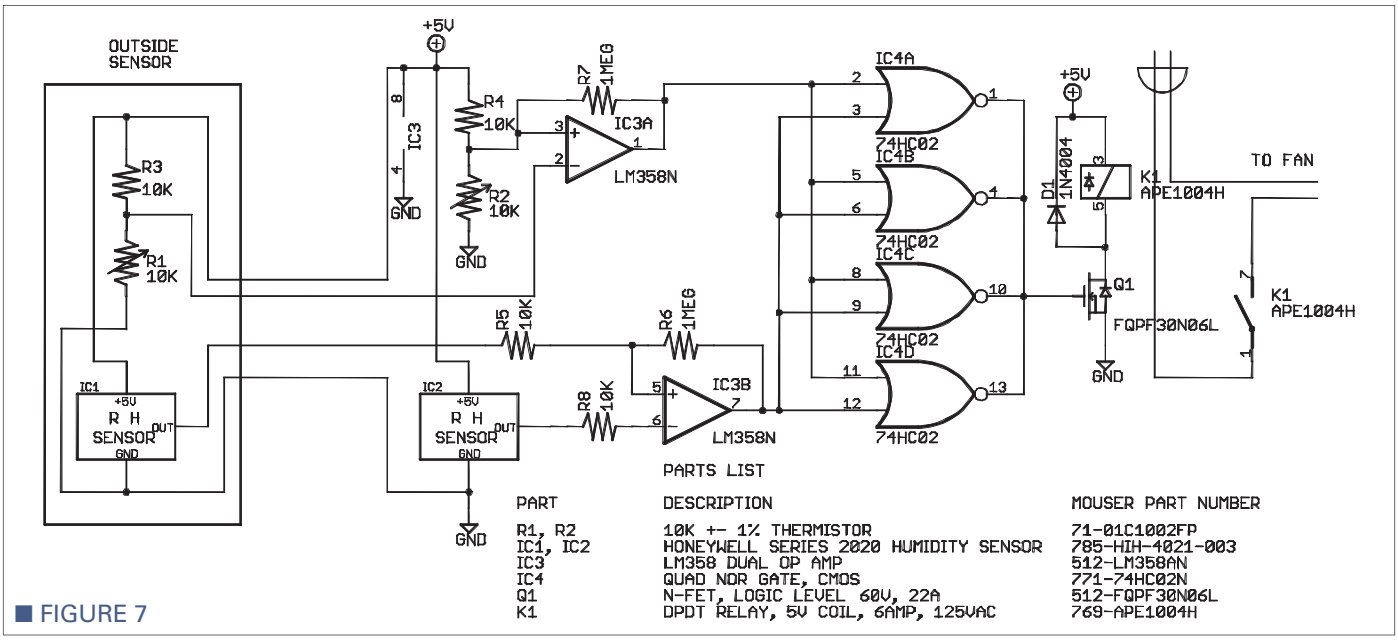
You are only interested in lightning protection, and lightning can happen without rain, so I recommend that you short out the rain sensor so it is always raining as far as the circuit is concerned.

I started out with a microcontroller solution but became frustrated with it not working, so I designed the discrete circuit of **Figure 3**. In **Figure 3**, rain will cause IC2A to be high which sets the output of IC1A high. The lightning detector is arranged such that when lightning causes a reduction in the resistance of R5, pin 6 of IC2B is pulsed high which makes its output low which triggers the timer, IC4. The output of IC4 goes high immediately and stays high for five seconds. If thunder happens within the five seconds, IC1B is clocked which makes its output high. Both inputs of IC3 being high, Q1 is turned on which switches the relay, K1. C3 resets IC1 on power-up; otherwise, its condition would be random. SW1 lets you reset the circuit after the storm. If you find the varistors burned or blackened after the storm, they should be replaced. The parts list is in **Figure 4**.

I went back to study the microprocessor circuit because I wanted to know why it didn't work. Finally re-reading the PIC12F675 documentation, I discovered that I had put the oscillator input to pin 2 (GP5/CLKIN), but pin 5 (GP2/T0CKI) is the designated input for the timer clock. With that change, it started to work, except IC2A (**Figure 5**) was oscillating at 1 MHz. Additional bypassing of the power supply did not help and a capacitor from pin1 to pin2 only changed the frequency; so I substituted an op-amp for the comparator and that solved the problem. I think the LM393 should have worked, so I left it in the schematic. If you have a problem with oscillation, try an op-amp. There is no parts list for **Figure 5**.

The PIC12F675 has two timers

A You can purchase a moisture detector or, I made one by placing two bare wires in a pill bottle cap and fixing them with epoxy (see **Figure 2**). The epoxy did not stick to the cap, so it would be better to drill holes and epoxy the wires in place. I tested the detector with distilled water from my A/C system; the dry resistance is open circuit and under 100K when wet. For the lightning detector, I used a cadmium sulfide cell from RadioShack, part number 276-1657. The detector is capacitive coupled to make it insensitive to sunlight (see **Figure 3**). You could purchase




■ FIGURE 7

but neither will count for five seconds using the internal clock, so an external clock is needed (LM555 oscillator). TMR0 has a max count of 255 so the clock has to be 51 Hz to overflow in five seconds (actually 4.999 sec.). When TMR0 overflows, an interrupt flag is set at bit 2 of the INTCON register (INTCON.2).

The schematic is **Figure 5** and the PICBASIC program is **Figure 6**. As usual, I can send you a programmed PIC12F675 for $5.00; just send your request to me in care of *Nuts & Volts*.

## FAN CONTROL

**Q** I would like to automatically turn on an exhaust fan only when the outside temperature and humidity is less than the inside temperature and humidity. Thank you for your help.

**— McLouis Robinet**

**A** The humidity sensor is a linear IC; a little taller than a TO-92 package. It is sensitive to light so it should be shielded from sunlight, as well as from rain. The temperature sensor is a thermistor which is nonlinear but since I am only comparing them, the nonlinearity is not a problem. The comparators (**Figure 7**) have positive feedback to provide hysteresis for clean switching. When the outside temperature is low (resistance is high), the signal to the negative input of IC3A is high causing the output to be low. When the outside humidity is low, the signal to the positive input of IC3B is low, causing the output to be low. The 74HC02 NOR gate is also an inverted AND. When both inputs are low, the output is high, turning on Q1 and energizing the relay. **NV**

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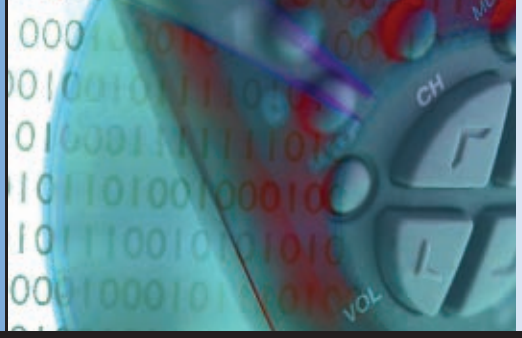

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The adapter features transfer rates of 300 baud to 3 Mbaud and is capable of interfacing with RS-422, RS-485, and RS-232 interfaces (additional signal leveling electronics are required). Professional users can use the royalty-free DLL software interface drivers from FTDI for full customization. The board features two LEDs: one for Transmit (blue) and one for Receive (green). It measures 30 mm x 20 mm (1.2 x 0.79 inches). Price is $17.90.

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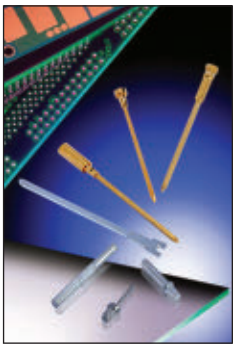

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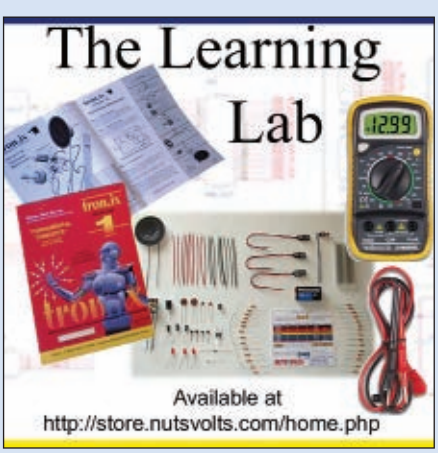

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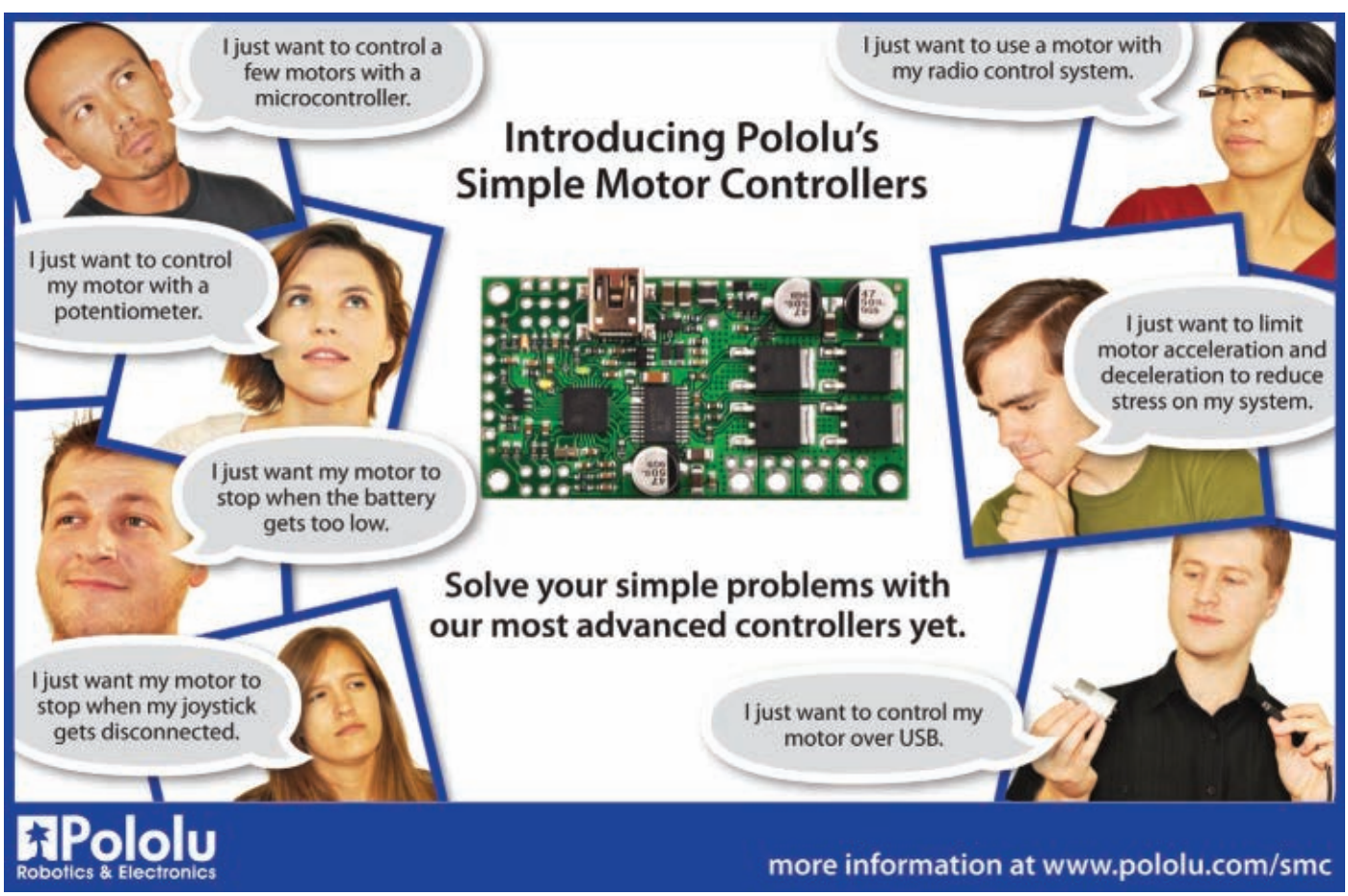

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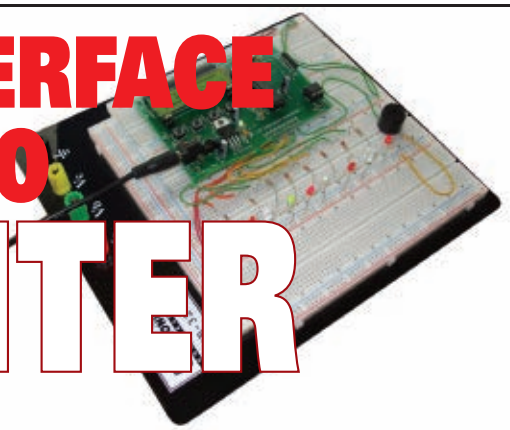
BY THOMAS KIBALO

# ENHANCED USER INTERFACE FOR THE 16-BIT MICRO EXPERIMENTER

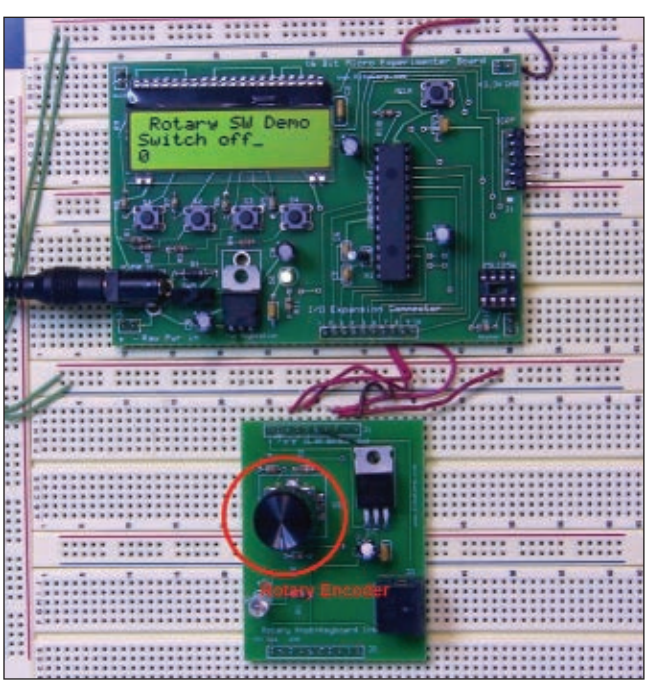


**This is the seventh in a series of articles describing the capabilities for the 16-Bit Micro Experimenter (Experimenter for short) and its associated hardware features (see previous articles in even months, starting with Dec '09). In this article, we will look at enhancing the Experimenter user interface with a rotary encoder using the PIC24F timer peripheral set and its interrupt capability. The timer peripheral is a significant component in the PIC24F peripheral arsenal. With the PIC24F timer, we can count external pulses or optionally count the internal 16 MHz PIC24F CPU clock as a timing source. All timer operations occur in hardware with a minimal need for software intervention — a really powerful capability to incorporate into Experimenter applications.**

There is a lot of ground to cover here, but no worries, because we'll supply code examples and schematics, as well as a mini-kit to help with these examples. As stated in earlier articles, all software will be kept to general level functional calls. However, some basic familiarity with C language syntax is required, as we will be incorporating some of the 'C' code libraries introduced in earlier *Nuts & Volts* articles that discussed the 16-bit Experimenter.

## Understanding the Rotary Encoder

Let's look at the rotary encoder and understand its operation. Most modern home and car stereos use mechanical rotary encoders for volume. They are also used in a variety of home appliances — like ovens — for temperature and timing settings. The rotary encoder is different from a potentiometer in that the encoder can undergo full rotation without limits. It is also different from a potentiometer in that we have two outputs: A and B. Each output signal is the result of the opening and closing of switches internal to the rotary encoder as its turns. To insure that digital signals are generated, the switch outputs are tied through pull-up resistors to +3.3 VDC, and the common is connected to ground. If a switch is open, a high voltage is generated; if closed, zero or low voltage is generated.



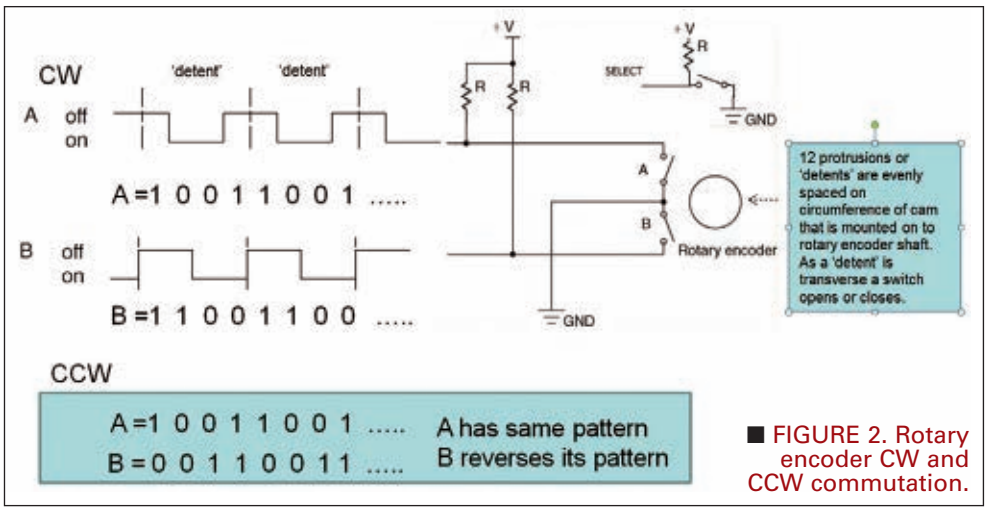

■ FIGURE 1. The Experimenter with rotary encoder.

Now let's imagine that the encoder internal shaft has two cams: one for A and one for B. Each cam has 12 "detent" or protrusions along its circumference that provide 360 degrees/12 or 30 degree resolution with each detent. As a cam turns, each detent opens or closes a switch to generate a waveform (see **Figure 2**). The A and B cams are placed 90 degrees from each other. Because of this placement, as the encoder shaft turns, the A and B output waveforms are 90 degrees out of phase (again look at **Figure 2**).

The microcontroller

samples any of these output waveforms and determines the amount of rotation. If time is also known, speed can be determined, as well. The final missing ingredient is the direction of shaft rotation CW or CCW; this is where both A and B waveforms are used together.

Waveform A is the same no matter what the direction of shaft rotation is. Waveform B reverses its order as the shaft turns from CW to CWW. By sampling both waveforms simultaneously and comparing them against one another, the microcontroller determines the direction of rotation.




■ FIGURE 2. Rotary encoder CW and CCW commutation.

With a rotary encoder, the microcontroller can determine direction, speed, and amount of rotation. All three of these physical phenomena can be used for operator input. For one of our demos, we will use the rotary encoder rotations and direction to cause up/down scrolling of text on the LCD display.

The specific encoder used in these demos is available from SparkFun (part number COM-09117). This encoder also has a built-in select switch (by pushing in on the encoder knob). We will use all these features in our first experiment.

## Let's Review the PIC24F Peripheral Timer

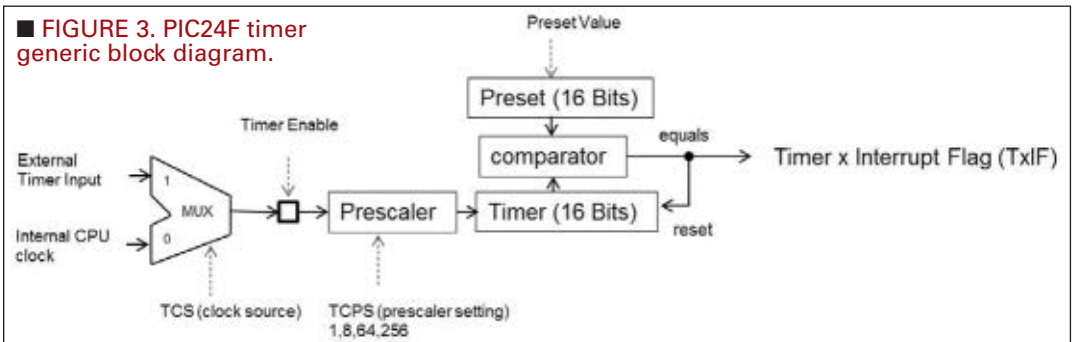
We need the PIC24F timer peripheral and its interrupt capability to work with the rotary encoder. We have plenty of timers with the Experimenter — five total (Timer 1, Timer 2, Timer 3, Timer 4, and Timer 5). A timer high level block diagram is shown in **Figure 3**.

Each element within the timer has its own set of controls that the microcontroller needs to initialize. Starting on the left side of the block diagram is the input clock source selection for the timer controlled by TCS (timer clock select bit). The TCS setting allows for either the external clock or the internal PIC24F CPU clock. The PIC24F internal clock is 16 MHz which is the clock we will use for our demo. The next control is Timer Enable that turns on the timer. The next stage is the prescaler that allows the clock to be scaled down by factors of 1, 8, 64, and 256. The prescaler is set using control bits TCPS (Timer Clock Prescaler set). All the control bits reside in an internal control register designated Timer Control (T1CON for Timer 1). The final element within the block diagram is the preset register and the timer register, both of which are16 bits wide. The microcontroller writes to the preset register to set the upper count range for the timer. During timer operation, the preset value is constantly compared against the running count value of the timer for a match condition. If a match occurs, a Timer Interrupt flag is latched to alert the microcontroller. Another action that occurs as a result of this latch is the reset of the timer register — this automatically starts the next timing cycle.

The Timer Interrupt flag can also cause an interrupt to PIC24F if interrupts have been enabled. This is the most efficient way for the microcontroller to perform periodic processing, and this is the approach we will use in our demo. There is a code snippet which shows both how the Timer 1 is initialized and how to enable Timer 1 interrupts (see **Figure 4**). In this snippet, the control bits for T1CON are set for internal, the prescaler is set to eight, giving us a final clock of (16 MHz/8) or 2 MHz. With preset set to 10,000, the timer will generate interrupts every five milliseconds (1/2 MHz*10,000). The five milliseconds are sufficient for capturing any rotation activity and will work well to debounce the A and B switches within the encoder (including the push switch).

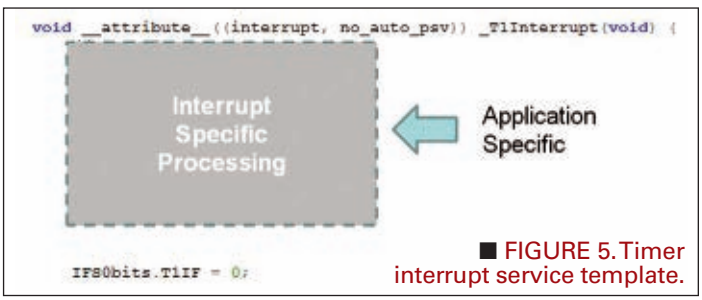
Interrupts appear in the PIC24F C code as unique function declarations as shown in **Figure 5**.

■ FIGURE 3. PIC24F timer generic block diagram.

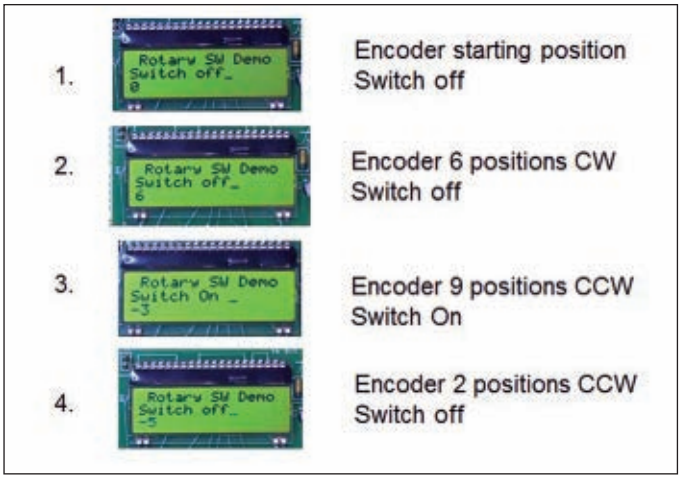


```
void TimerInit(void)
{
    //set for ev 5 msec
    PR1 =  10000;
    IPC0bits.T1IP = 5;
    T1CON = 0b1000000000010000;  //prescaler =8  TON =1
    IFS0bits.T1IF = 0;
    _T1IE =1;       //enable interrupts

}
```

■ FIGURE 4. Timer initialization.




■ FIGURE 5. Timer interrupt service template.




■ FIGURE 6. Rotary encoder display demo.

Interrupt functions accept no parameters and return no parameters (note the use of void), and each interrupt source has its own specific function call. The code that executes during an interrupt function is called the "interrupt service routine." General recommendations for writing an interrupt service are: First, perform the minimal essential processing needed for the service (that is, get in and out quickly); and secondly, do not call any other functions during the service. Finally, an interrupt service must reset the original interrupt flag that initiated the interrupt before exiting. If the interrupt service communicates with other parts of the program, then this communication must occur through the use of shared variables.

## Interfacing to a Rotary Encoder Using Timer 1

For this demo, we use Timer1 with interrupt service to process rotary encoder outputs. As the encoder knob is turned, the Experimenter LCD displays the direction and amount of rotation of the encoder. In addition, the display also shows the condition of the SELECT switch (that is part of the encoder) as ON or OFF, depending on whether you push in the knob. The demo uses the LCD library that was discussed in previous Experimenter articles. **Figure 6** shows the LCD display. The hook-up diagram is shown in **Figure 9**. The demo in **Figure 8** is an excellent way to test your rotary encoder and verify its proper operation.

Let's take a closer look at the interrupt service. With a continuous five millisecond interrupt, the interrupt service code samples Output A and determines if it is changing in value from previous samples or remaining the same. If A goes high to low, the code will then look at Output B and make a determination on direction. Only during CCW operation — when A goes high to low — will Output B be zero. If this CCW condition is not detected, the rotation direction defaults to CW. In all cases where Output A changes from a low to a high, the condition will count as a detent movement.

The interrupt service reports the current encoder position and rotation using two variables: (D for direction (1 = CW, -1 = CCW) and RCOUNT (rotational count). RCOUNT will increment or

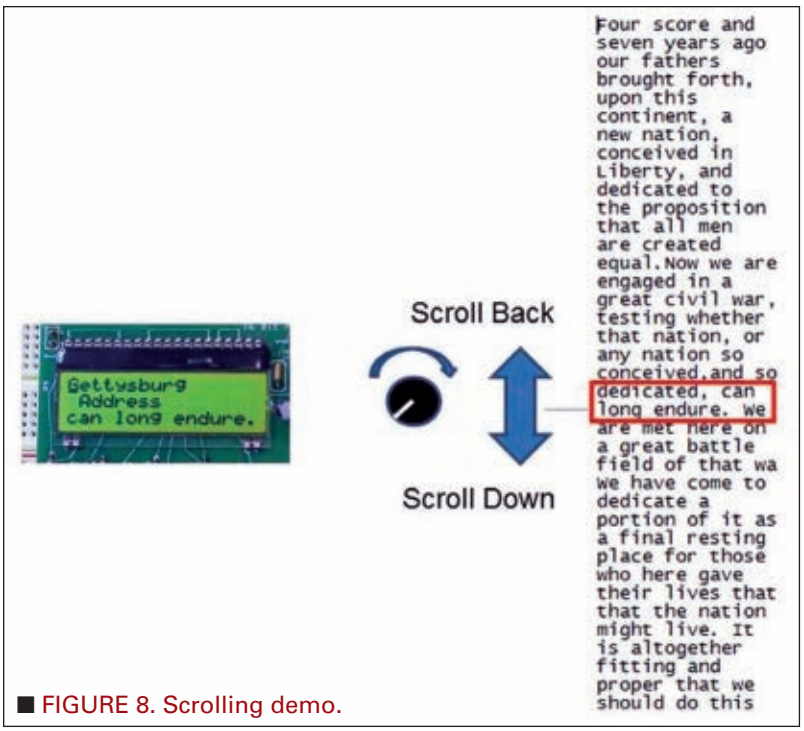
```
//T1 interrupt -rotary encoder service
void __attribute__((interrupt, no_auto_psv)) _T1Interrupt(void) {

    static char d;          // direction variable
    switch (RState) {
        default:
        case R_IDLE:        // idle waiting on a change
        if (! ENCHA)        //test if A output to go low from high
        {
        RState =R_DETECT;   //yes, change state
        if (! ENCHB)        //check if B output is low direction=CCW
        d =-1;
        }
        else                //else by refault direction is CW
        d =1;
        break;
        case R_DETECT:
        if (ENCHA)          //test if A output going high from low
        {
            RState =R_IDLE;  //yes, change state
            RCount +=d;      //increment count
        }
        break;
    } //switch
    //debounce switch knob push switch
    if (SW==1)                  // debounce for knob test switch
    debounce =0;
        else debounce++;
    if ((debounce>=10) && (SW==0) )
    SWITCH =1;
    IFS0bits.T1IF = 0;
}
```

■ FIGURE 7. Timer1 interrupt service routine.

decrement in value based upon rotational direction. As a final function, the interrupt service routine determines the knob switch state (ON, OFF) and provides debounce for this switch. The Timer 1 interrupt service code is shown in **Figure 7**.

## Scrolling Text Display Application Using the Rotary Encoder

The first demo verifies operation of the rotary encoder. How about a demo that uses the encoder in a real application? In this second demo (Scrolling demo.MCP), we use the encoder to assist the user in scrolling through a large amount of text that is stored in the microcontroller Flash memory and viewed on the LCD. Our Experimenter LCD is a 16 x 3 display, limiting how much text we can view at a time. In this demo, we have hardcoded President Lincoln's entire Gettysburg Address in microcontroller Flash. The speech is approximately 1,172 characters and 64 lines of text. The rotary encoder will be used to scroll backward and forward to facilitate viewing the entire speech one line at a time.




■ FIGURE 8. Scrolling demo.

We use the same interrupt and timer set-ups as in the earlier demo, and to this add two new functions:

- **Scroll Down()** — This function advances forward to the next line of text in the speech. For each rotary detent, it retrieves this line for display and halts when it reaches the last line of the speech.
- **Scroll Back()** — This function moves backwards to the previous line of text in the speech. For each rotary detent, it retrieves this line for display and halts when it reaches the first line of the speech.

**Figure 8** shows the scrolling demo in action. Enjoy!

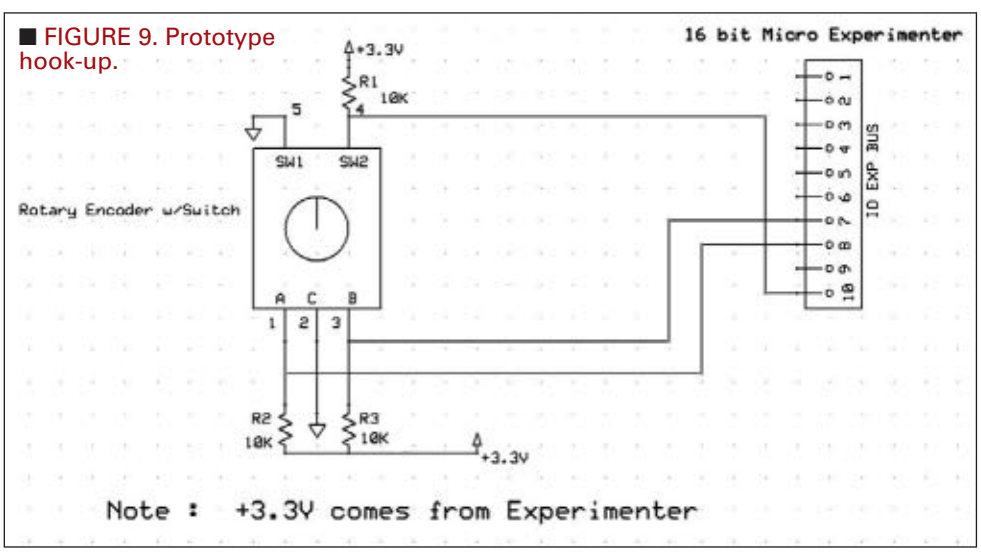
## Where To Go From Here

We have covered a new interface capability for the Experimenter. The rotary encoder really increases our "bag of tricks' and has wide applicability. We also discussed the PIC24F timer and its interrupt capability, applying timers to interface to these input devices.

Timers are a broad subject and there are many uses for them. A good reference book for this material and other applications is available in the *Nuts & Volts* Webstore entitled *Programming 16 bit Microcontrollers in C* by Lucio Di Jasio. For your convenience, there is mini-kit for this article containing all interface electronics, mechanical connectors, and the associated printed circuit board available from *Nuts & Volts*. The mini-kit not only contains a rotary knob interface but also a full PS/2 keyboard interface. We'll cover more of this keyboard interface at another time. **NV**

**The "Mini Kit" used in this article can be purchased online from the *Nuts & Volts* Webstore at www.nutsvolts.com or call our order desk at 800-783-4624.**

■ FIGURE 9. Prototype hook-up.




■ FIGURE 10. Rotary Encoder Parts List.

| Qty | Part List | Source |
|---|---|---|
| 3 | 10K Resistor | Various |
| 1 | Rotary Encoder | SparkFun.com COM-09117 |

# PUT A TEMPERATURE SENSOR IN YOUR NEXT ARDUINO PROJECT

By Rob Reilly

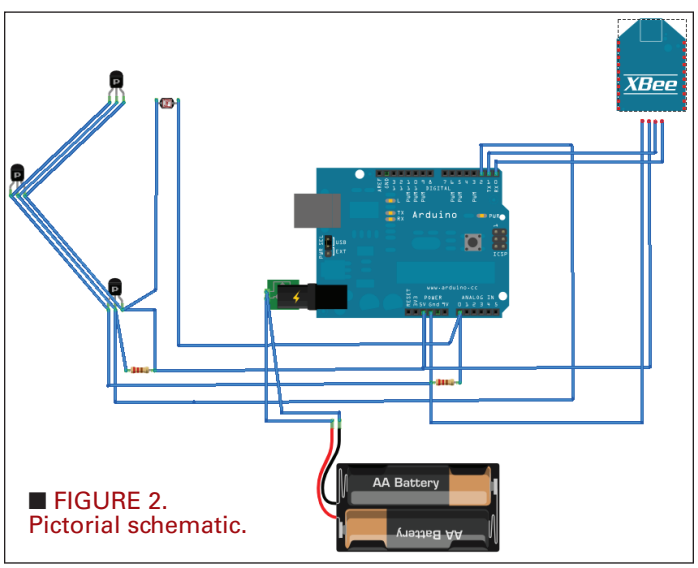
■ FIGURE 1. Compost temperature device.

**This project is a compost monitoring device (Figure 1) that uses three temperature sensors (Dallas DS18B20), a photocell, an Arduino, and an Xbee digital radio to wirelessly send telemetry data to my notebook. Temperatures are a good indicator of the need for turning the compost or when it is ready for use around my plants. My device is housed in PVC pipe and runs on four D cell batteries.**

In this article, I'll cover using the Dallas DS18B20 temperature sensor with the Arduino microcontroller. I'll briefly describe the sensor, then summarize the Arduino code needed for using one or several of them. We'll finish up with practical design implementation for putting these bad boys into your own device. The sensors are inexpensive and work well with the Arduino. You'll find a lot of uses for them.

## A Cool Little Device

The Dallas DS18B20 "one-wire" temperature sensor is actually an amazing piece of technology. It can measure temperatures from -67 degrees to 257 degrees Fahrenheit and operates on 3.0 to 5.0 volts DC. The TO-92 version is physically similar to a medium-sized LED. Each device has a unique serial number and is hooked up to a simple bus wiring layout. You can put one, two, or 10 devices on a cable and retrieve each one's data individually. It's called a one-wire because you can chain multiple devices together and read them all using one digital input line on your microcontroller.




■ FIGURE 2. Pictorial schematic.

Code to integrate the DS18B20 and the Arduino used to be complicated and hard to understand. Today, easy-to-use function calls to pre-built libraries are the way to go. The one built by Miles Burton works very well and makes reading temperatures from the DS18B20 device almost painless (see **Websites Sidebar**).

## Put the System Together

**Figure 2** shows the

pictorial layout of the Arduino, the DS18B20s, and the other related parts. **Figure 3** shows the schematic. The pictorial layout was generated with the Fritzing CAD package. The program is a work in progress, so I had to doctor the finished picture a little with the **OpenOffice.org** Draw graphics program. **Figure 4** shows a screenshot of the Fritzing program.

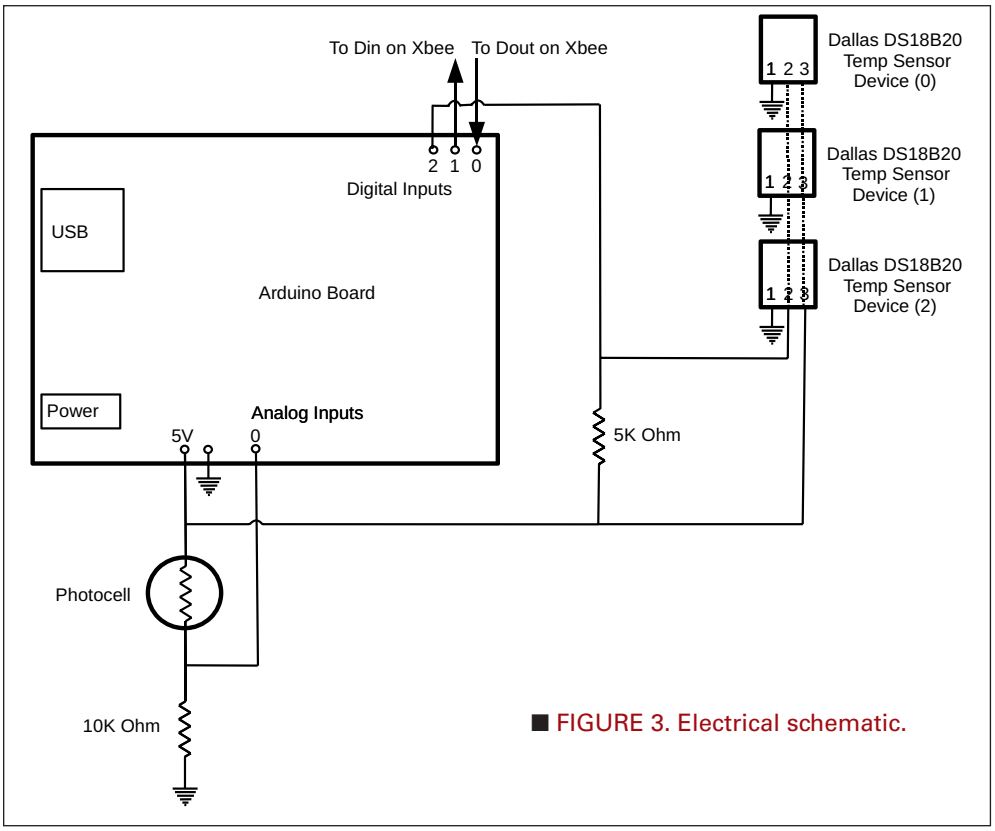
The Dallas sensors connect to the simple three-wire bus with the data line going to a digital input pin on the Arduino. Since the DS18B20s are running in "powered mode," the other leads just connect to the +5 volts and ground.

I soldered the Dallas sensors directly to the little three-wire cable I made for the prototype. For ease of ssembly/disassembly, I added male pins to the end of the cable so it could be plugged into the headers on the Arduino board. The sensors were mounted on the outside of the probe's lower tube with a dab of hot glue. The wire was passed through the tube and was sealed with more hot glue.

Using the library is straightforward. Download the library file, unzip it, and install it in the Arduino IDE's "libraries" directory. Add the reference to the library to your Arduino code and then call the temperature reading function in the main loop.

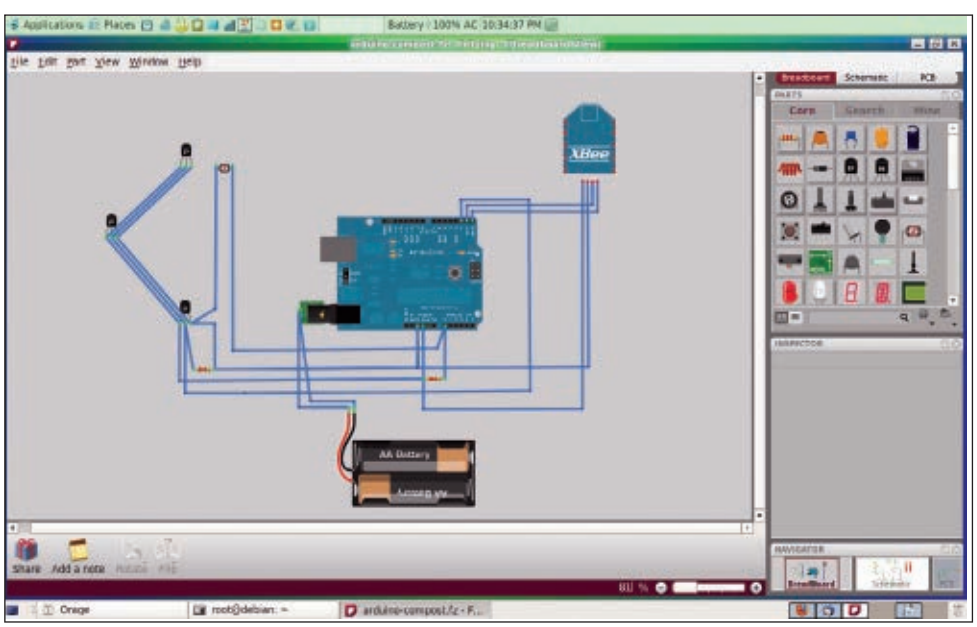
The code for the working prototype compost device is shown in **Code 1**. You'll notice the library reference at the beginning and the call to the temperature function in the Serial.print lines containing the "sensors.getTemp CByIndex" reference. Since the function returns the temperature in Celcius, a simple math function (c2f) was used to convert the value to Fahrenheit.

You'll also notice that the multiple sensors are indexed with separate function calls. Devices are indexed as 0, 1, 2, and so on. I wired up the three sensors, powered up the device, and then watched which value changed as I touched each device. Changes in the values are obvious due to the quick response and sensitivity of the devices.




■ FIGURE 3. Electrical schematic.

■ FIGURE 4. Fritzing CAD program screenshot.



## RESOURCES

Components and parts are available from the following sources:

SparkFun
**www.sparkfun.com**

Adafruit
**www.adafruit.com**

Home Depot
**www.homedepot.com**

## CODE 1

```
#include <OneWire.h>
#include <DallasTemperature.h>

// Data wire is plugged into pin 2 on the Arduino
#define ONE_WIRE_BUS 2

// Setup a oneWire instance to communicate with any OneWire
// devices (not just Maxim/Dallas temperature ICs)
OneWire oneWire(ONE_WIRE_BUS);

// Pass our oneWire reference to Dallas Temperature.
DallasTemperature sensors(&oneWire);

int val = 0;
int lightval = 0;
int potPin = 0;

void setup(void)
{
  // start serial port
  delay (3000);
  Serial.begin(57600);
  Serial.println("Dallas Temperature IC Control Library
  Demo");

  // Start up the library
  sensors.begin();
}

// celcius to fahrenheit conversion
float c2f(float val) {
  float aux = (val * 9 / 5);
  return (aux + 32);
}

void loop(void)
{

  lightval = analogRead(potPin);   // read the value from
                                   // the sensor


  // call sensors.requestTemperatures() to issue a global
  // temperature request to all devices on the bus
  // Serial.print("Requesting temperatures...");
  sensors.requestTemperatures();
  // Send the command to get temperatures
  // Serial.println("DONE");

  // Serial.print("Temperature for Device 1 is: ");
  Serial.print("c0001|");
  Serial.print(lightval);
  Serial.print("|");
  Serial.print(c2f(sensors.getTempCByIndex(0)));
  // You can have more than one IC on the same bus.
  // 0 refers to the first IC on the wire
  Serial.print("|");
  Serial.print(c2f(sensors.getTempCByIndex(1)));
  Serial.print("|");
  Serial.println(c2f(sensors.getTempCByIndex(2)));
  delay (20000);
  // 20 second delay between data line output

}
```

Make note of which sensor corresponds to each data value in your output data stream.

My projects focus on capturing log data, then pushing it to some type of plotting system. Taking a temperature reading from about once a second up to once every five minutes works well enough for my purposes.

The readings are packaged up using print statements and sent over the serial line to my Linux notebook. I capture the data from the serial line using a simple "cat /dev/ttyUSB0 > rob.txt &" command line on the notebook. The kst program then plots the data using the rob.txt file as input. **Figure 5** shows a screenshot of sample captured temperature data using kst.

Getting the data from the Arduino to my notebook is via a pair of 2 mw Xbee digital radios acting as a serial connection. You can also connect a USB cable between the Arduino and notebook. The cable configuration is typically used for programming and troubleshooting. Naturally, the serial connection (digital pins 0 and 1) should be disconnected between the Arduino and Xbee when hooking up the USB cable. Otherwise, you'll get an error when attempting to upload a program from the Arduino IDE. I upped the communication rate from the default of 9600 to 57600 bits/second.

## Standard Design Practices

Effectively using the Dallas sensors means installing them in your projects, so that they report the desired temperature in a predictable and reliable way.

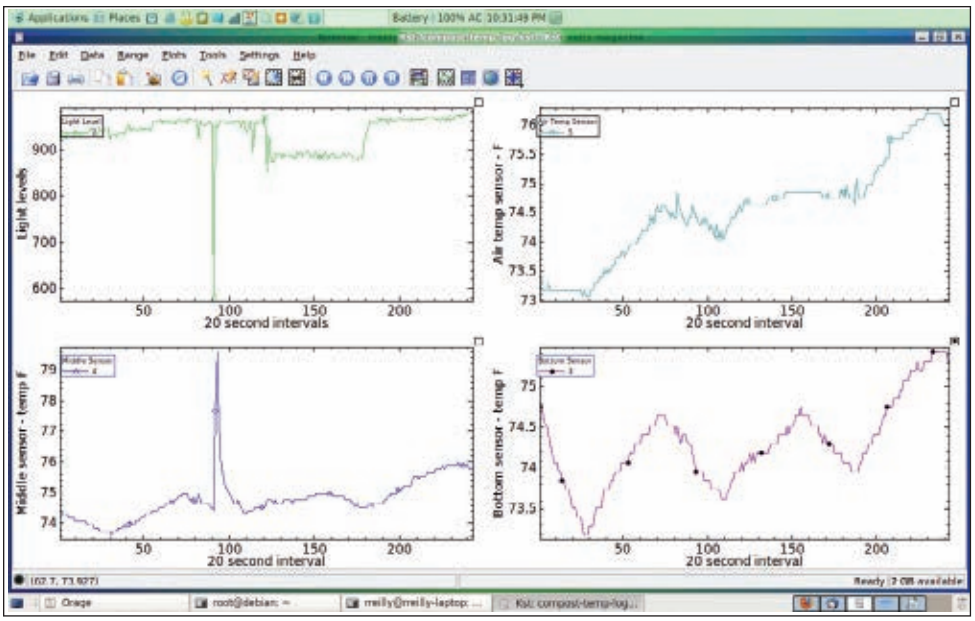
There are four main challenges to successfully adding the Dallas sensor to your project. They include placement in your device, shielding, connections, and protecting the device.

## Placement and Shielding

My design for the compost temperature probe called for a sensor to measure ambient air temperature, two sensors to measure temperatures down in the compost, and a photocell to record the amount of sunlight falling on the heap.

I originally mounted the air

■ FIGURE 5. The kst plotting program screenshot.




temperature sensor at the very top of the compost device, putting it above the Arduino and the Xbee digitial radio (**Figure 6**). Testing, however, showed that the readings were consistently between six and seven degrees F higher than the other two sensors when the device was in its vertical (installed) orientation, in free air. My suspicions were confirmed when the device was positioned horizontally on the floor with the top sensor detached from the housing. This isolated the sensor from the Arduino and Xbee. After a few minutes, all three temperature readings settled to within 1/2 degree F of each other.

The Arduino and Xbee dissipate about 85 milliamps at five volts. This was enough inside the enclosed housing to heat up the sensor and throw the temperature off. The simple solution to the problem was to mount the sensor away from the Arduino and Xbee. On the compost device, I moved the sensor from the top of the main housing (which contained the Arduino and Xbee) to the bottom. The sensor was then below and away from the Xbee. The same effect could have been accomplished by keeping the sensor on the top, but elevating it a couple of inches higher on the end of an insulating piece of plastic.

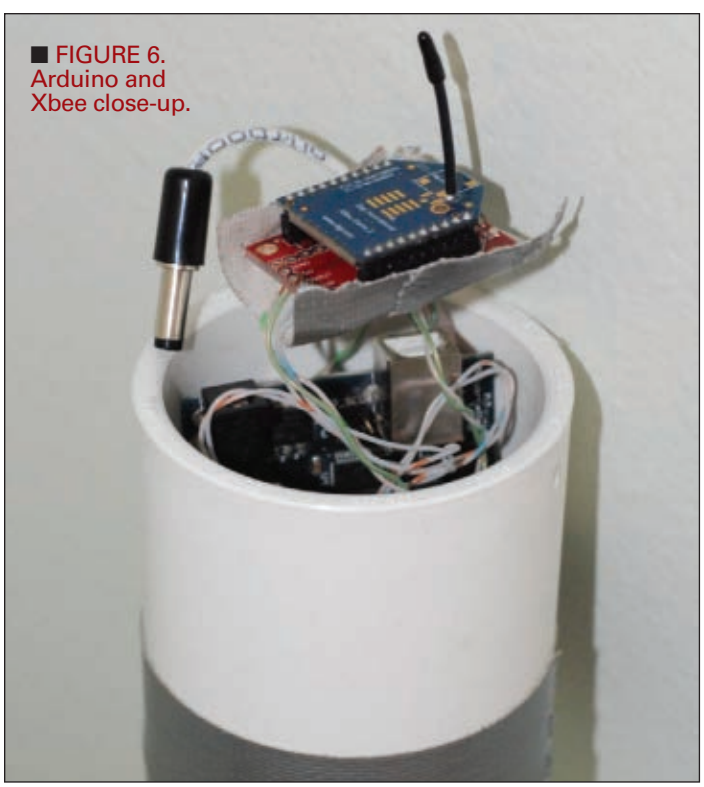
I didn't go with this latter fix because that would have made the sensor vulnerable to physical damage. Putting a tiny Dallas device at the end of a stick on the top of the tube was an invitation to have it broken off when adding material to the compost bin. Sensors need to be bulletproofed, especially when they go on a device that may be unattended for extended periods of time.

The sensors are sensitive enough that air currents and direct sunlight will alter their readings significantly. I couldn't figure out why the middle sensor had wild swings of temperature over a five or 10 minute period when the device was leaning up against a tree in the back yard. I found that the sun was shining directly on the middle sensor, but not on the other two. Clouds and the tree's leaves blocked the sunlight part of the time, explaining the temperature variations. Make sure you thoroughly test your physical world devices to learn their particular behaviors.

## Connections

You'll want to seal all connections at the devices because any shorts (such as a drop of water across the data line and ground) will cause the reading to go haywire. This problem appeared the first time I sprayed the probe with the hose, while it was installed in the compost pile. I had to go back and add more hot glue around the sensors where they attached to the tube.

■ FIGURE 6. Arduino and Xbee close-up.



## Websites

kst plotting program
**http://kst.kde.org**

DS28B20/Maxim site
**www.maxim-ic.com/products/1-wire**

Fritzing CAD program
**http://fritzing.org**

Miles Burton DS18B20 library
**http://milesburton.com/index.php?title=Dallas_Temperature_Control_Library**

■ FIGURE 7. Dallas sensor mounting.

## Protecting the Sensors

Although the Dallas sensors are small and fairly rugged, they should be protected from physical damage with some kind of a guard or by careful placement on your device.

The sensors on my compost monitor are exposed to sticks and the sharp end of the shovel when it's being installed in a pile. That is okay on a prototype (**Figure 7**), but will need to be addressed before production is started on the real thing. A smooth little plastic cover or spot of epoxy will probably do the trick.

Lastly, make sure you don't exceed the temperature range of the device. Don't put a sensor in direct contact with a glowing heating element if you just want to measure the temperature in an enclosed space. Otherwise, the device will likely be destroyed.

## Wrap-Up

We've seen that the Dallas DS18B20 sensors are easy to use with the Arduinos. Although a little more expensive than using a thermistor, the DS18B20s are very accurate and accommodate multiple sensors on a single input pin. This arrangement can satisfy a wide range of temperature monitoring situations.

You might also explore some of the other Dallas one-wire devices. They include memory modules, clocks, a digital potentiometer, and more. Now that you have exposure to this data input methodology, maybe some of the other types of devices will satisfy your design needs.

Give the Dallas sensor a try. No doubt, you'll start dreaming up some really interesting applications. **NV**

*Rob Reilly is a technology consultant, writer, and portable computing expert. Early adopter tech trends, seminars, and media projects are his stock-in-trade. Links to many of his published articles appear on his website at* ***http://home.earthlink.net/~robreilly****. Contact Rob at robreilly@earthlink.net.*

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**100 for 50¢ each**

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**CAT# SPL-61**

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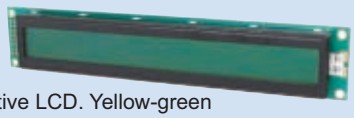
**100 for $3.25 each**

## 40 CHARACTER X 2 LINE LCD W/ LED BACKLIGHT



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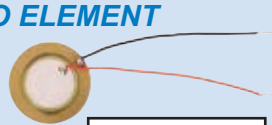

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# WIZARD DUELING WANDS

By Ron Newton

**Harry Potter had just entered a cold, dank chamber in the tombs of Hogwarts. His scar started to hurt and he had a feeling of impending doom. The chamber was ill lit, but he barely could make out candles on the sacrificial altar. Harry pointed his wand and commanded, "INCENDIO!" The candles lit. He observed a dark foreboding figure in the corner ... it was Voldemort. His wand was raised and pointed at Harry. Both gave their wands commands at the same time. "INCENDIO CRUCIO!" yelled Voldemort. "STUPEFY!" cried Harry. A scream was heard and a red light could be observed coming from the heart of ... ?**

**Who won? Well, it depends on the players.**

This project builds two wands, two candles, and two badges. It uses six Microchip 12F508s. If you don't have a programmer, the chips are available pre-programmed. All three of the assembly files are located on the *Nuts & Volts* website (**www.nutsvolts.com**). Click on "Magazines" and then "Downloads" and look for the issue. The schematics can also be found on the website, along with several helpful files. The cost per set in parts is $14 + boards. There are no small surface-mount components.

## IR Transmitter and Receivers

One might think that you could just use a light emitting diode (LED) and photodiode to transmit signals for your TV and other electronics. The problem occurs if there are any bright lights that can falsely trigger it. This is overcome by transmitting a medium frequency, i.e., 36 kHz, and modulating this signal on and off in binary code. This technique is known as PCM or pulse code modulation which was discovered back in 1937. The receiver has an input amplifier, automatic gain control, band pass filter, and a demodulator with feedback. Not bad for a chip that costs $1.10. Once the receiver determines that the frequency being received is at 36 kHz, it demodulates it and changes its output to a high or low. When a signal is detected, its output is low.

Most circuits use a 555 timer for triggering IR transmitters. These circuits require a minimum of nine parts with a large capacitor. Each 555 has to be tuned to the frequency of the receiver and can drift.

The Microchip PIC12F508 needs none of these extra parts. Each of its five outputs can sink 25 milliamps and they can be paralleled as drivers up to 75 milliamps. Vishay has recently come out with a long range IR detector and a high powered IR LED. The Vishay TSAL6100 can take up to 100 milliamps continuous and up to 1.5 amps for short periods of time.

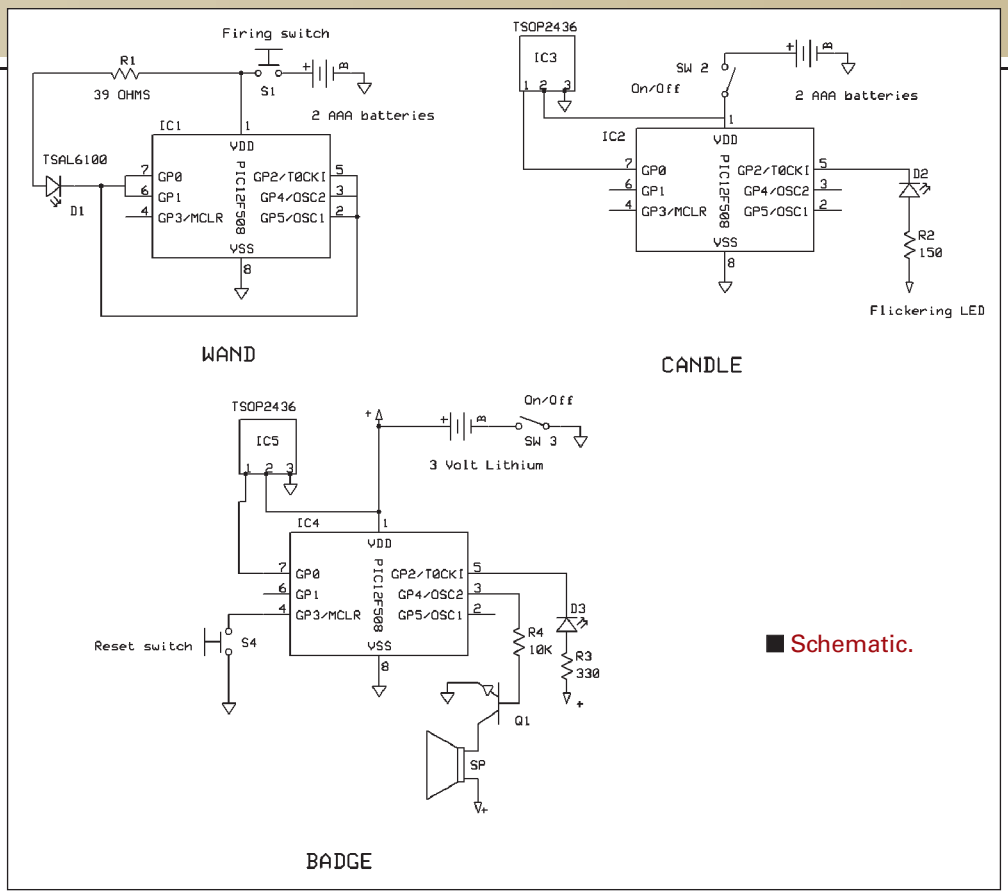
The wand PIC12F508 uses three volts and is powered by the momentary switch. All of its outputs are tied together to drive the TSAL6100 IR diode at 30 kHz. It stays on for about 70 milliseconds. The TSAL6100 was chosen due to its high output and its narrow 10° beam.

The receivers use the new Vishay chip and have a range of 40 meters or 120 feet (versus 10' with the standard TV remote) and detect the 36 kHz signal to

prevent spurious outputs. Both the badges and candles interface with a PIC12F508 for control. When the detector detects a 36 kHz signal, it pulls its output low.

## Wand

When the momentary switch is pressed, it applies power to the chip. The program is about as simple as you can get. It has two peripheral registers for timing and uses a series of NOPs to lock down the 36 kHz frequency. It produces a square wave output on all five outputs. Each PIC12F508 has an internal oscillator which is trimmed at the factory. Once it's programmed, no adjustment for frequency is necessary. The two registers provide a 70 milli-second pulse. This prevents the person from holding down the button and cheating. They have to re-push the button. The wand uses two AAA batteries for power.



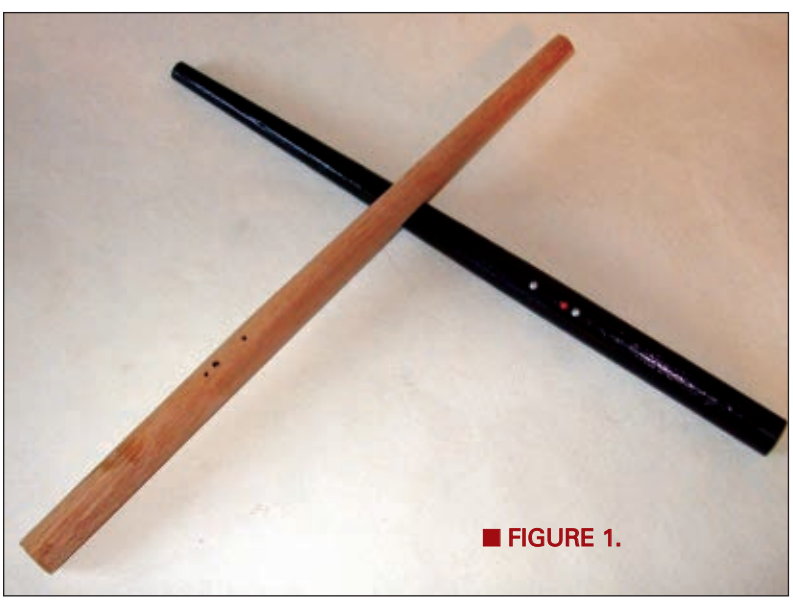

■ Schematic.

## Candle

The candles also use two AAA batteries, have an on/off switch for power, and are triggered via a Vishay TSOP2436 infrared receiver. A yellow LED flickers using a random number generator when the IR beam hits the IR detector. It can be turned off again if the IR beam is again detected. There is a built-in delay to prevent false signaling. The IR receiver draws 3 ma; this is why a power switch is needed.

## Badge

The badges are powered by a three volt lithium battery and also have an on/off switch. They use the same Vishay detector. If an IR beam is detected, it will light the red LED and emit a squeal from the piezo buzzer. For each hit, the buzzer counts the score. The score counter can be reset by pressing the reset switch. When it reaches 10, the badge will stop counting and will need to be reset.

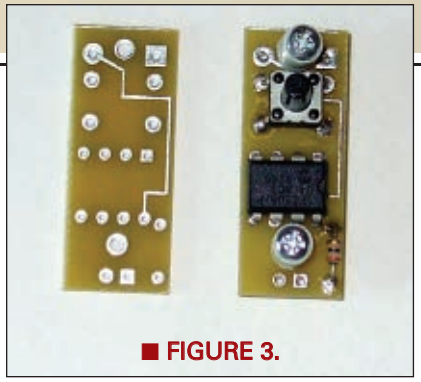


■ FIGURE 1.

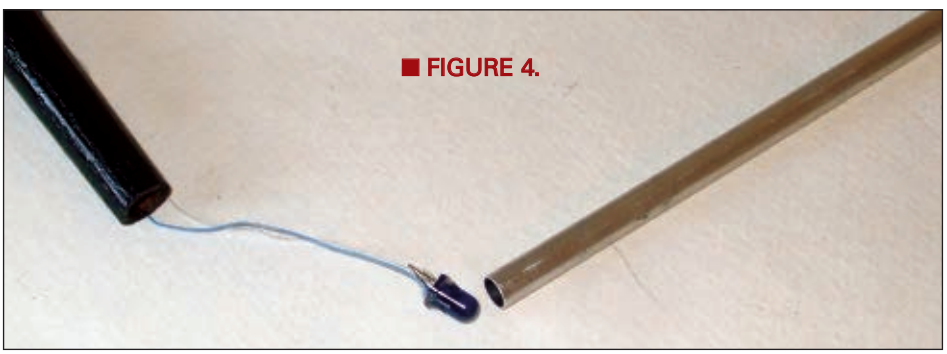
## Construction: Wands and Candles

The wands are made out of 14″ pieces of 3/4″ hardwood dowels. (See **Figure 1**.) Do not use pine or poplar as it will split. (The plans and dimensions are located on the *N&V* website.) Locate the center of the dowel. Using a center drill, center drill both ends. Drill the 5/8″ hole first to 5.5″. Remove the 5/8″ drill and using an extended 1/4″ drill, drill halfway through the remaining portion of the wand. The drill will center in the 5/8″ hole. Reverse the dowel and using the extended 1/4″ drill, drill the dowel completely through. The candles are made the same way, only they are 8″ in length. You will find that the main problem is the drilling of a continuous 1/4″ hole as

■ FIGURE 2.



■ FIGURE 3.



■ FIGURE 4.

## PARTS LIST

| ITEM / DESCRIPTION | | QTY | SOURCE |
|---|---|---|---|
| **WIZARD'S WAND** | | | |
| IC1 | PIC12F508 | 1 ea | Microchip |
| D1 | IR emitter 10 degree | 1 ea | Vishay TSAL6100 |
| R1 | 39 ohm 1/6 watt | 1 ea | |
| S1 | Momentary switch 9.5 mm | 1 ea | E-Switch TL1105BF100Q |
| Battery holder | Two AAA series | 1 ea | |
| Nylon spacer # 2 1/4" | | 2 ea | |
| 1/4" Aluminum tube 8.5" | | 1 ea | |
| 3/4" Hardwood dowel 14" | | 1 ea | |
| **WIZARD'S CANDLE** | | | |
| IC2 | PIC12F508 | 1 ea | Microchip |
| IC3 | IR DETECTOR | 1 ea | Vishay TSOP2436 |
| D2 | 5 MM LED Yellow | 1 ea | |
| R2 | 150 ohm 1/6 watt | 1 ea | |
| S2 | Dip Switch; 1 pos | 1 ea | |
| Battery holder | Two AAA series | 1 ea | |
| Nylon spacer #2 1/4" | | 2 ea | |
| 3/4" Hardwood dowel 8" | | 1 ea | |
| **WIZARD'S BADGE** | | | |
| IC4 | PIC12F508 | 1 ea | Microchip |
| IC5 | IR detector | 1 ea | Vishay TSOP2436 |
| Q1 | NPN KSP2222A | 1 ea | |
| D3 | LED red | 1 ea | |
| R3 | 330 ohm 1/6 watt | 1 ea | |
| R4 | 10K 1/6 watt | 1 ea | |
| S3 | DIP Switch one pos | 1 ea | |
| S4 | Momentary switch 6 mm 9.5 mm | 1 ea | E-Switch TL1105F250Q |
| SPK | Piezo buzzer | 1 ea | Soberton Inc GT-0903A |
| Battery holder 12 mm coin | | 1 ea | Keystone Electronics 3000TR |
| Lapel pin | | 1 ea | Sewing shop |
| **MISCELLANEOUS:** | | | |
| Wire-wrap red and white | | | |

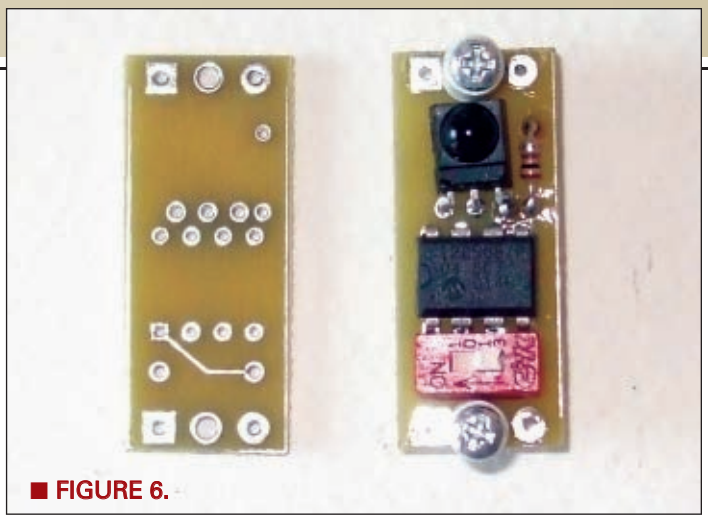
the drill will follow the grain of the wood. If you are not into wood working, the *Nuts & Volts* store has both the wands and candles available.

Note the mounting holes are slightly different for the candle than they are for the wand. There are templates on the website to locate these holes. Download the templates, cut them out, and put them on the dowels using glue. Drill the indicated holes. Taper both the candles and wands by sanding. Paint or stain the wands black or brown, and paint the candles white or any other color you choose. Only the last two inches of the candles need to be tapered as shown in **Figure 2**.

## Wand Boards

The board files provide for two sets and are available on the website, along with the boards themselves. Two mounting holes are located on the board and should be tapped with a 2-56 tap. The component side is labeled with the components. Solder the micro noting that pin 1 is the square hole (**Figure 3**). The long momentary switch is then soldered along with the resistor. Cut eight inches of red and eight inches of white wire-wrapping wire and solder the red wire going to the + pad just below the switch (square pad) and the white to the round pad.

Take a 1/4" O.D. aluminum tube and cut to 8.5 inches. Smooth both ends. Check to see that it will slide down the 1/4 hole with a small amount of effort. You may need to increase the size of the 1/4" hole by running the drill several times back and forth. Take the IR diode and wire-wrap an eight inch piece of red wire to the long lead. Perform the same using an eight inch white wire to the short lead. Place a small bead of hot glue around the lip of the LED



■ FIGURE 6.

and put in side one of the ends of the aluminum tube. Avoid getting glue on the dome of the LED. Slide the wires down the wand and push the tube inside the wand. Fix with hot glue if loose. The wires should extend out of the battery compartment end of the wand. This tube will narrow the beam even further and prevent light from being absorbed by the wood. Refer to **Figure 4**.

You are now going to solder the wires from the IR diode to the board. Cut the wires to a length that you can still solder. Solder the red to the square pad and the white to the round pad. Use the 2-56 screws, add the standoffs, and screw to the board on the component side. Affix the standoffs to the board using hot glue. Once set, remove the screws. Slide the board into the wand, allow the switch to enter its hole, and attach using two each of the 2-56 machine screws.

Take the battery holder and tack the red wire to the bottom side of the battery holder using a glue gun. Cut both the black and red wires of the battery holder to about 1/2" from the end of the battery holder. Add a short piece of shrink tubing to each wire coming from the board. Wire-wrap the red wire with the red wire coming from the board and the white wire to the black battery holder wire. Solder each wire and insulate each wire with the shrink tubing. Slide the battery holder into the wand. Friction will hold it in (**Figure 5**).

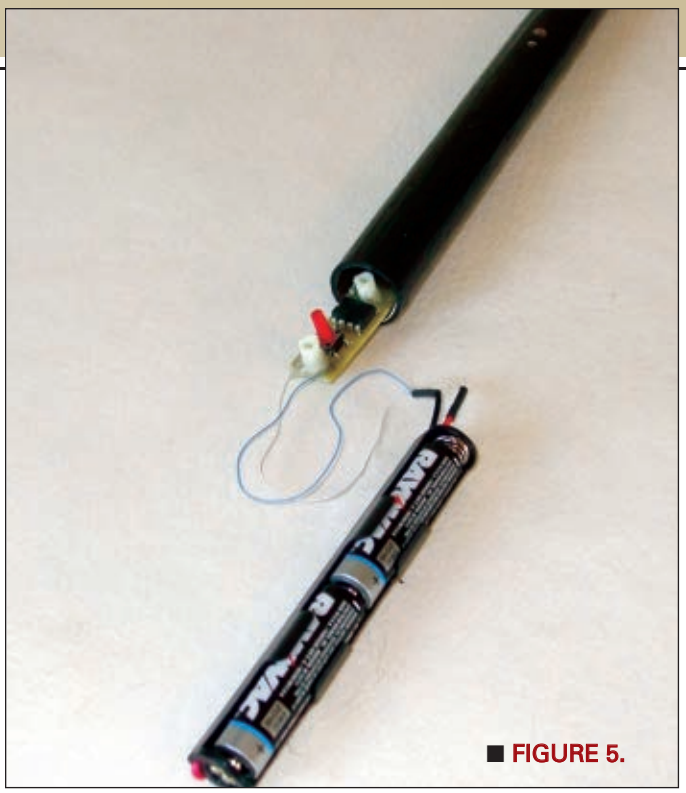
## Candle Board

Tap the mounting holes with a 2-56 tap. Solder the PIC12F508 pins; pin one to the square pad. Bend the leads of the IR detector down at a right angle with the lens pointing up from the plastic. Solder the IR detector to the board. Solder the 150 ohm resistor and the on/off switch to the board. (See **Figure 6**.)

Cut two pieces each of 8" red and white wire-wrap wire; solder the red wires to the + or square pads, and the white wires to the round pads on both ends of the board. Glue the spacers to the board.

Feed the two wires next to the photo detector down the 1/4" hole. Slide the board into the 5/8" hole and secure it using two each of the 2-56 machine screws.

Prepare the battery holder as above and solder the



■ FIGURE 5.

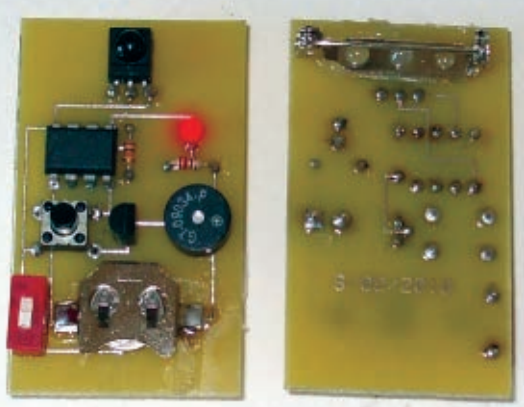
wires from the board to the battery holder wires. Use the shrink tubing to prevent shorts. Slide the battery holder into the candle. Cut the red and white wire to about one inch from the tip of the candle. Wire-wrap the red to the long lead of the yellow LED and the white to the short lead. Push the excess wire down the candle. Affix the yellow LED to the candle using a hot glue gun.

The circuitry is very straightforward. The micro is put in an endless loop until the IR detector senses a signal. It will then turn on and the LED will flicker. It is once again put in an endless loop until it detects an IR signal. It will turn off the LED and start over again.

## Badge

Solder in the PIC12F508 noting pin 1 is the square hole. Solder in the transistor noting the flat side (towards the sound module) and the sound module noting the +.

■ FIGURE 7.



Solder the LED. Its anode (long wire) goes to the square hole. Place a small drop of solder on the center square of the battery holder for contact of the battery. Solder the battery holder next, and then the switches. The badge uses a 12 mm lithium battery (CR1225).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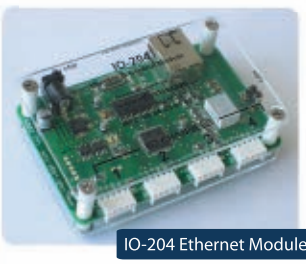

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The badge operates the same as the candle. When the IR detector senses the IR, it brings the positive voltage to ground. The LED then turns on and the micro generates a 4 kHz square wave which causes the piezo buzzer to squeal. Check out **Figure 7**.

Several counters are used to generate the sound and the number of pulses indicating the number of hits.

A safety pin clip is glued to the back of the board so that it can be placed over the heart of the player. Glue some felt to the back to prevent it from snagging clothing by the leads.

## The Game

Insert the batteries into the wand, candle, and the badge. Turn on the switches.

*Two players*: The game is played indoors and in subdued light. (Florescent lights can cause false readings.) Each player pins a badge over their heart and has a wand. They can be back to back, take 10 paces, and fire, or they can just face each other and count down. When the IR hits the IR detector, the badge will light and emit a sound. This scores one point. (See **www.youtube.com/watch?v=vEPhYhKdJ7k** to view the Harry Potter and Malfoy duel.)

*Single player:* The candles can be used as a target to improve the player's accuracy. Also, the player can stand in front of a mirror with their badge and practice hitting their own badge. Happy Wizardry! **NV**


**PCBs, programmed MCUs and Wands to go with this article can be purchased online from the *Nuts & Volts* Webstore www.nutsvolts.com or call our order desk at 800-783-4624.**



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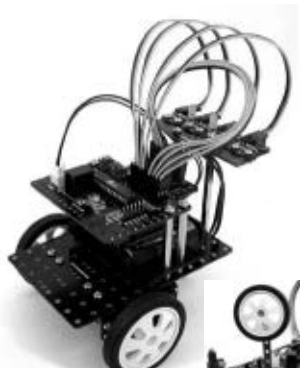

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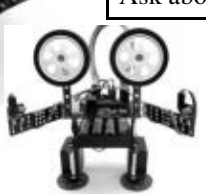

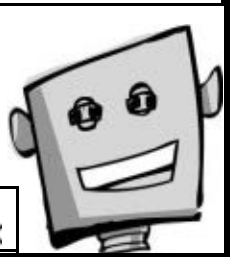

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worldmags

# The Projects of PROTOTYPE THIS

With Joe Grand

# The Wristband GPS Transmitter

Figure 1. The pneumatic cannon ready for action on Stinson Beach (*photo by Boj Florido*).

*(All photos and figures by Joe Grand unless otherwise noted.)*

Prototype This — an engineering entertainment program on Discovery Channel — offered a view into the real-life process of designing and building unique prototypes. In this 13 episode series which was filmed over the course of 18 months and aired starting back in October 2008, we set out to tackle the problems of today by creating crazy, one-of-a-kind inventions of tomorrow. I was the team's electrical engineer and hardware hacker, and shared the screen with Zoz Brooks, a roboticist and software designer specializing in human-machine interaction; Mike North, a material scientist and mechanical engineer; and Terry Sandin, a special effects veteran. We were challenged to build things that had never been done before, looked cool on TV, and could be completed within the extremely tight financial and time constraints of television production. It was a fantastic adventure and great experience to say the least!

This quarterly series of articles covers the electronic aspects of some of my favorite projects from the show. My hope is that you will be inspired, learn something new, or use my work as a building block for your own open source project. Let's begin!

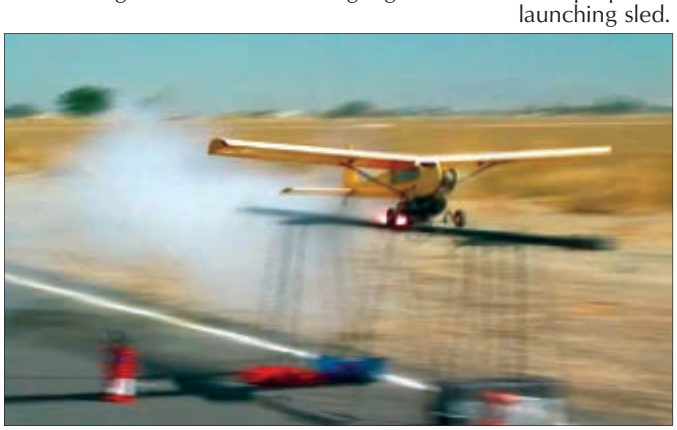
## The Flying Lifeguard

The Flying Lifeguard episode followed our trials and tribulations in prototyping two different lifeguard systems to save a swimmer in distress on an unguarded beach. The goal was to autonomously deliver a water-activated, self-inflating lifejacket to within a few feet of the person.

The first system we built was for short-range rescues of swimmers close to shore, such as within the breaking waves. A pneumatic cannon (**Figure 1**) automatically rotates and adjusts its firing pressure based on the location of the person.

The second system was for long-range rescues, such as for a swimmer stuck in a rip current who may be a mile or more out from shore. We instrumented a large model airplane (**Figure 2**) with an MP2028g UAV (Unmanned Aerial Vehicle) system by MicroPilot (**www.micropilot.com**) and a custom payload-dropping

Figure 2. Our UAV taking flight off of a rocket-propelled launching sled.



mechanism (that held the lifejacket). Zoz modified some of the control scripts for the MicroPilot system to direct the airplane to the desired dropzone with pinpoint accuracy. This system emulates practices by the US Coast Guard in which rescue equipment, food, or other payload is manually dispensed from an airplane flying over the person or vessel in distress.

The two systems were disparate efforts going on in parallel, but they both relied on a critical piece of information — a distress signal and location coordinates from the person in the water. Both systems required the swimmer to wear a small, battery-powered wristband transmitter that — when enabled by a button — would transmit his GPS coordinates to the receiving base station (**Figure 3**). Those coordinates — along with additional data such as wind speed, wind direction, and distance to the target — would be processed by the cannon or UAV control system, and a rescue attempt would commence.

This system received the GPS transmissions sent from the wristband and processed them accordingly.

This article details the wristband GPS transmitter used for both systems. While the episode as a whole was extremely complicated, this piece is very simple. It requires minimal hardware and firmware, and is something you'll be able to quickly put together and incorporate into your own location-tracking projects.

If you want a complete look into the Flying Lifeguard episode, all technical documentation I created for the build, including schematics, source code, and development notes is available on my website at **www.grandideastudio.com/portfolio/pt-flying-lifeguard**/.

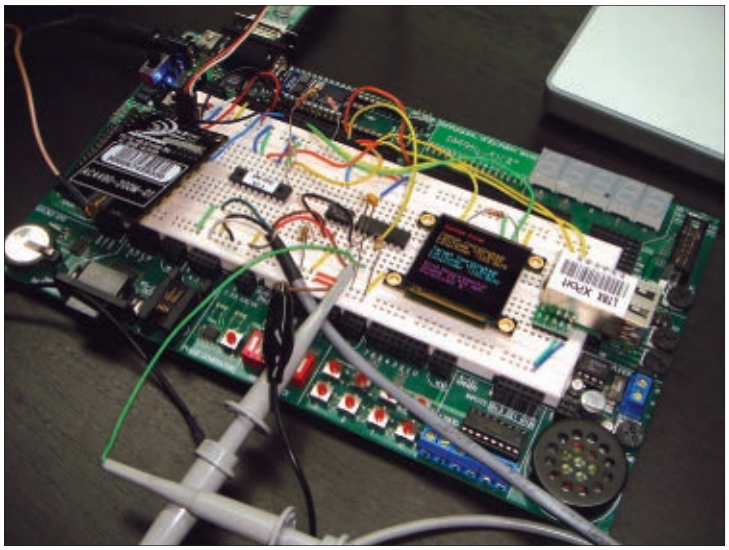
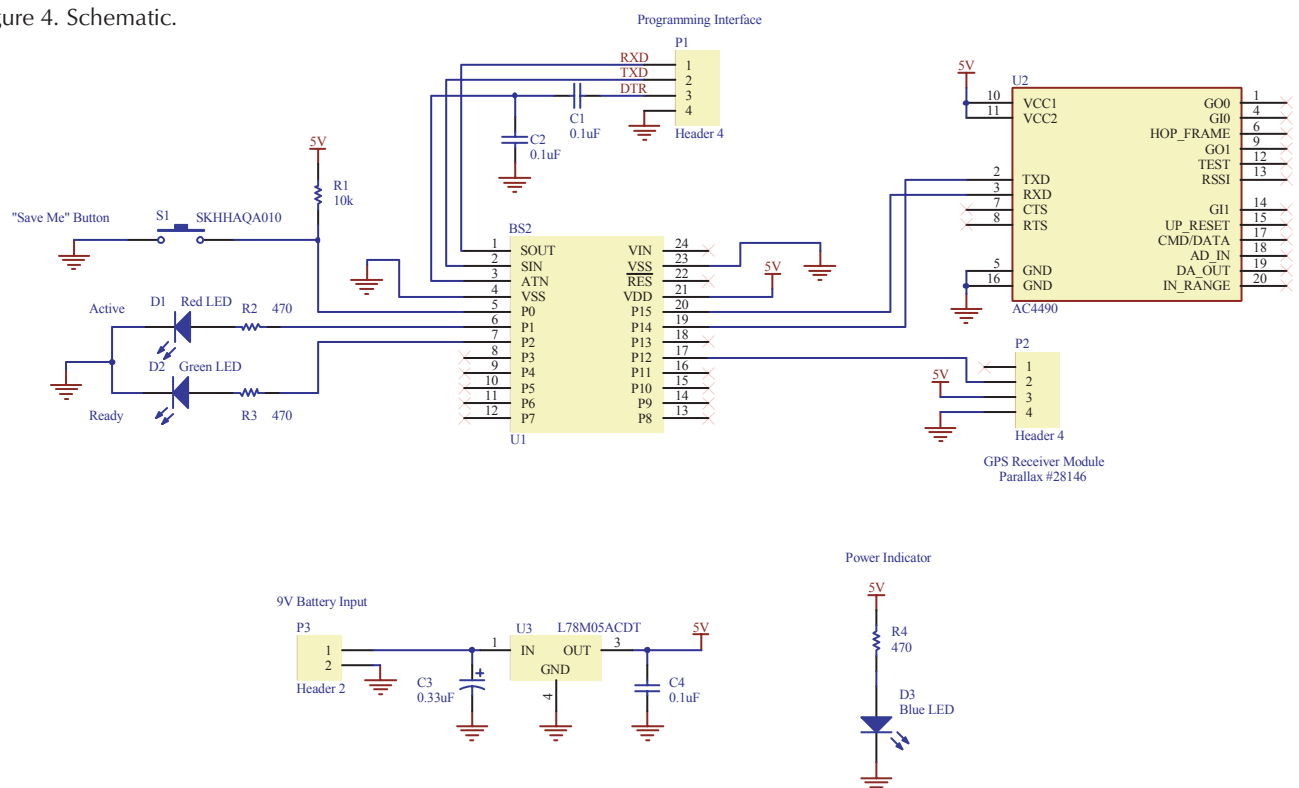


Figure 3. Base station circuitry built on a Parallax Professional Development Board.

# The Hardware

The wristband GPS transmitter's core hardware components are a BASIC Stamp II, Parallax GPS receiver module, and AeroComm (now Laird Technologies) AC4490-200A 900 MHz RF transceiver module which

Figure 4. Schematic.



| Item | Quantity | Reference | Description |
|---|---|---|---|
| 1 | 3 | C1,C2,C4 | Capacitor, 0.1uF, 50V ceramic, 0805 |
| 2 | 1 | C3 | Capacitor, 10uF, 16V tantalum, size A |
| 3 | 1 | D1 | LED, Red, 1206 |
| 4 | 1 | D2 | LED, Green, 1206 |
| 5 | 1 | D3 | LED, Blue, 1206 |
| 6 | 1 | P1 | Connector, BS2 programming interface (do not populate) |
| 7 | 1 | P2 | GPS Receiver Module, Parallax #28146 |
| 8 | 1 | P3 | Connector, 9V battery |
| 9 | 4 | R1,R2,R3,R4 | Resistor, 470 ohm, 5%, 0805 |
| 10 | 1 | S1 | Switch, SPST pushbutton, PCB mount, SKHHAQA010 |
| 11 | 1 | U1 | BASIC Stamp II microcontroller, DIP24W |
| 12 | 1 | U2 | 900MHz RF transceiver, Laird Technologies AC4490-200A |
| 13 | 1 | U3 | Linear regulator, L78M05ACDT 5V @ 500mA, DPAK |

Table 1. Bill of Materials.

contains an on-board gigaAnt chip antenna. Refer to the schematic (**Figure 4**) and bill of materials (**Table 1**) for details.

The AC4490 module, U2, is a frequency hopping spread spectrum (FHSS) transceiver that operates in the unlicensed 900 MHz ISM (industrial, scientific, medical) band. It is designed as a drop-in replacement for wired connections and takes in TTL-level serial data, packetizes it as necessary, and broadcasts it wirelessly. Once the module is properly configured, all you need to do is send and receive serial data as you would if two devices were directly connected together — no need to worry about any of the underlying wireless protocols or theory (unless you want to, of course). You can achieve distances upwards of four miles with the right conditions, such as line-of-sight and proper antenna selection. The module provides advanced control via an AT command set, and has optional DES encryption and a choice of wireless network architectures (point-to-point, point-to-multipoint, client-server, or peer-to-peer). D1, D2, and D3 serve as LED indicators. The blue LED, D3, is the power indicator. The green LED, D2, illuminates when the GPS receiver has acquired satellites and is ready to go. D2 will blink if the GPS receiver has not yet acquired the minimum number of satellites. The red LED, D1, illuminates when the GPS coordinates are being transmitted.

A single 9V battery connected through a ubiquitous 5V linear regulator, U3, provides power for the system.

# The Firmware

Like the hardware, the code required for the wristband GPS transmitter is straightforward.

Upon power-up, the system initializes itself which consists of configuring the input and output pins, waiting for the GPS receiver to attain a lock on the satellites, and then waiting in a loop until the "distress" button (S1, noted as the "save me" button on the schematic) is pressed.

Once the button press is detected, the system retrieves the current GPS coordinates (using function calls borrowed directly from the stock demonstration code on Parallax's GPS receiver web page).

```
GOSUB GPS_Get_Lat
GOSUB GPS_Get_Long
```

Then, the coordinates are transmitted to the base station in a single stream of serial data. The ASCII 'A' and 'B' characters serve as a header and footer, respectively, for the data packet. This makes it easier for the base station receiver to know where the actual start of data is.

```
SEROUT RF_TX, RF_Baud, ["A", degrees, minutes,
       minutesD.HIGHBYTE, minutesD.LOWBYTE,
       dir, long_degrees, long_minutes,
       long_minutesD.HIGHBYTE, long_minutesD.
       LOWBYTE, long_dir, "B"]
```

After that, the system sets the "transmitting" LED indicator.

```
       LOW LED_Active
       PAUSE 1000
```

What happens next is a bit confusing and written primarily for ease-of-use during filming. In most real-world cases, once the person presses S1, he would want his coordinates to be transmitted continuously until he was rescued. However, in my case, I wanted to be able to start and stop the coordinate transmission at will using the single button. If S1 is quickly pressed and released, the GPS coordinates will be transmitted over and over again. If S1 is still held down after the coordinates have been sent, the system will reset and the transmission will stop. So, quick push to start, long push to stop.

```
IF (Alarm_Trigger = 1) THEN
' keep transmitting until button is pressed
' GOTO SendGPSAgain
   ELSE       ' if button is held down after
              ' transmitting, reset system
WaitForDepress:
     IF (Alarm_Trigger = 0) THEN GOTO
     WaitForDepress
              ' wait for button to be released
     GOTO Init
  ENDIF
```

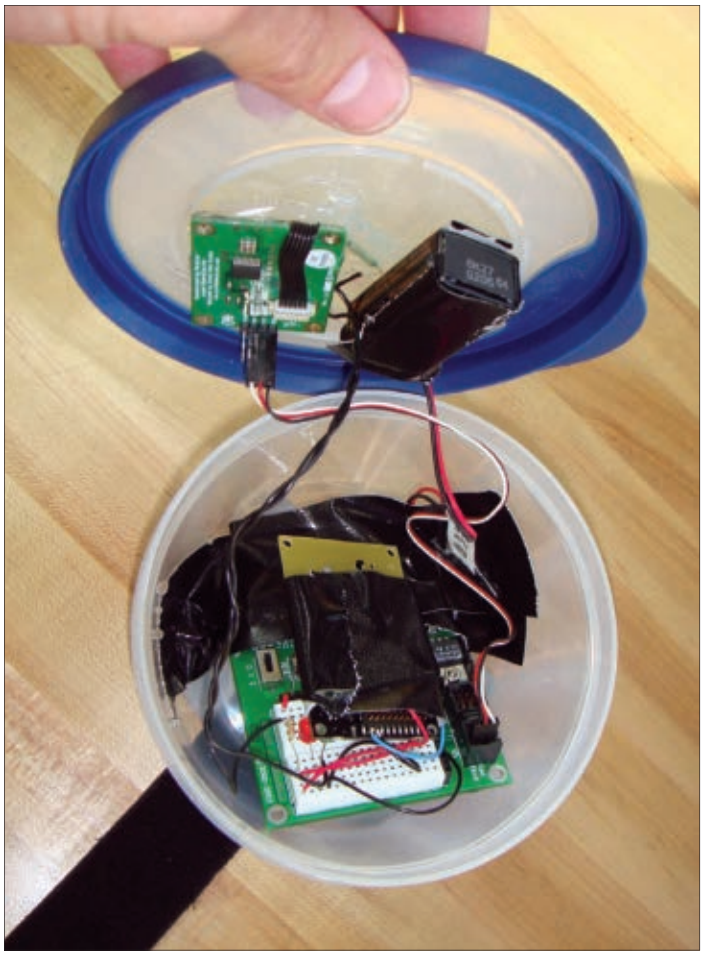
To remove my start/stop feature and change the code to transmit coordinates repeatedly after a single press of S1, you can just call GOTO SendGPSAgain immediately after the PAUSE command and erase the check of Alarm_Trigger.

# The Design Process

After sketching the design on paper, I built a quick

worldmags

Figure 5. Prototype circuitry mounted in a waterproof Tupperware bowl and held together with tape. The great thing about prototypes is that they don't have to be pretty to get the job done!



prototype using a BASIC Stamp Board-of-Education with the GPS receiver and AC4490 connected to it with wire harnesses. We'd be using this version for some real-world testing, so it had to be waterproof. I crammed it into a Tupperware bowl and held it all together with some Gorilla Tape and hot glue (**Figure 5**). Instead of using a pushbutton switch that would require me to physically activate it within the waterproof enclosure, I used a reed switch mounted inside the lid and enabled the system with a magnet.

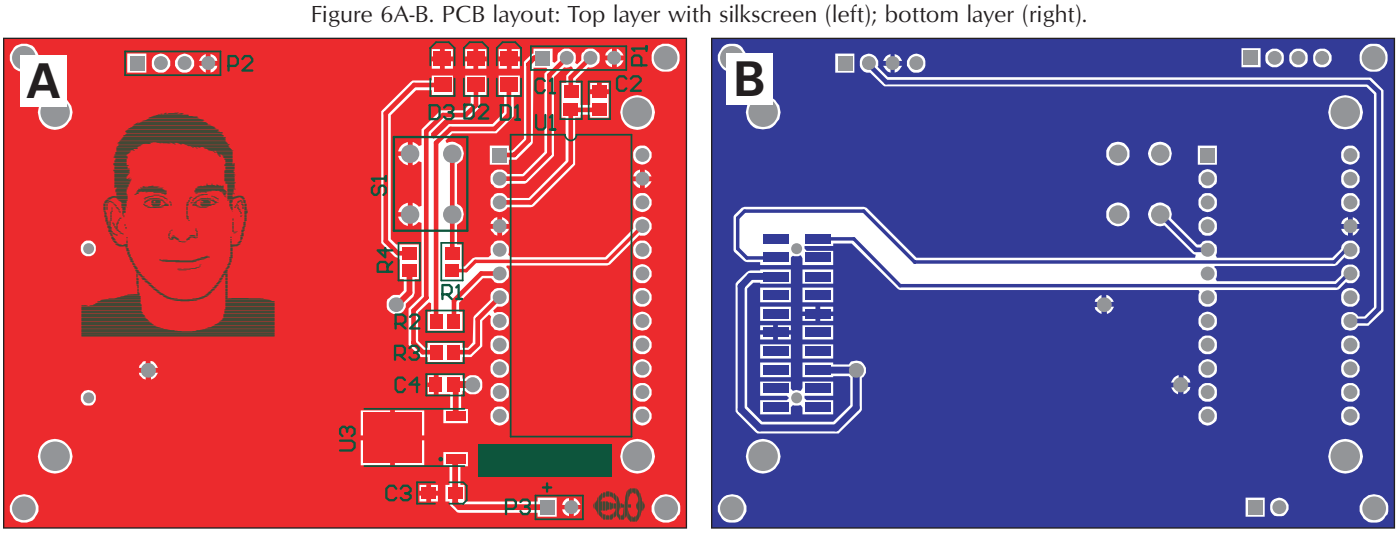
In the small cove outside our warehouse in San Francisco, I swam out approximately 20 meters with the bowl and circuitry strapped to my arm. After verifying that Zoz could receive my GPS coordinates, I increased my distance from shore little by little until I was almost at the other end of the water. Our tests were enough to prove that the concept worked and I proceeded to design the custom circuit board for our "production" model.

Since there are very few components in the circuit, designing and routing the PCB was relatively painless. The final board was two layers and measured 2.9 inches long by 2.1 inches wide (**Figure 6**).

**Figure 7** shows the final assembled unit. The AC4490 module connects to my board via a double-row header on the back side. The front side of the board contains all the other components. While I could have spent time dramatically shrinking the design by replacing the larger off-the-shelf modules with discrete GPS and RF functionality and going with a smaller microcontroller and battery, it wasn't necessary. This design worked just fine for our purposes. The 9V battery (not shown) sits to the side of the board.

As the finishing touch, Zoz used Rhino 3D to design a two-piece, arm-mountable enclosure (**Figure 8**) complete with red "distress" button (which made physical contact with the pushbutton switch on the PCB) and Prototype This logo. The circuitry and battery sit snugly inside. The enclosure was printed out on a Z-Corp Z450 multicolor 3D printer — a rapid prototyping tool that builds solid models out of layers of powered plaster glued together one after another. To make the enclosure waterproof, the two halves were infiltrated with epoxy and sealed together with silicone.

Figure 6A-B. PCB layout: Top layer with silkscreen (left); bottom layer (right).



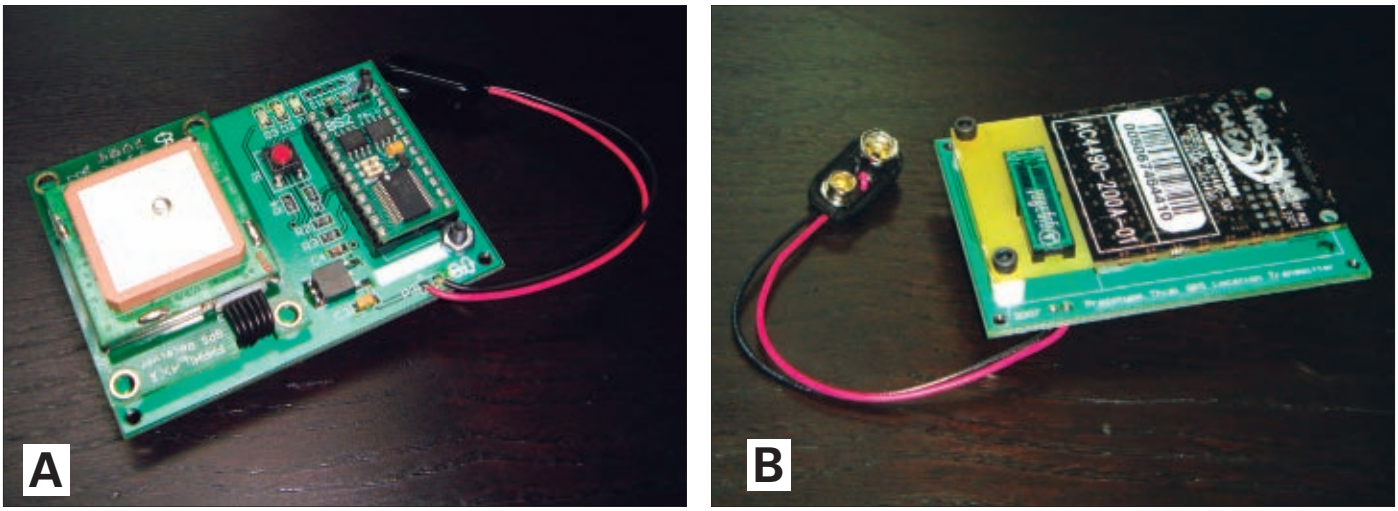



Figure 7A-B. Fully assembled unit: Top (left) and bottom (right).

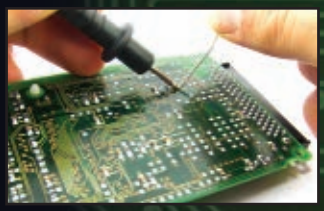
## Swimming with the Fishes

Either because of my affinity for swimming or because the producers liked me the least, I was chosen to serve as the test dummy for the finale of the episode as we tested both lifeguard systems. I found myself bobbing up and down in the frigid waters of the San Francisco Bay Area's notorious Red Triangle (**http://en.wikipedia.org/wiki/Red_Triangle_(Pacific_Ocean)**), where around 38 percent of all documented great white shark attacks have occurred. Although the accompanying lifeguards assured me they'd never seen a shark, I only hoped that I wouldn't need to use our system to send a real distress call! I tried to convince myself that at least if something did happen, it would be captured in high definition.

Besides sea sickness, getting clobbered by waves, and a few numb extremities, I came away from testing day unscathed. Both systems proved to be effective and reliable solutions for unmanned beach rescues. In the future, maybe lives will be saved with lifeguard systems like ours installed on beaches around the world. But, for now, I can only hope that you'll enjoy using this wristband GPS transmitter in your own projects! **NV**

Figure 8. The completed wristband GPS transmitter mounted in its waterproof housing.

Joe Grand is an electrical engineer, hardware hacker, and president of Grand Idea Studio, Inc. (**www.grandideastudio.com**), where he specializes in the invention, design, and licensing of consumer products and modules for electronics hobbyists. He can be reached at joe@grandideastudio.com.



# GREAT PROJECTS TO BUILD THIS WINTER

## SOLAR KITS FOR KIDS

**3-In-1 Solar Robot Kit**
**KJ-8928 $14.50 plus postage & packing**
An exciting project that will keep the kids occupied for hours! This 3-in-1 solar robot kit easily transforms into three intergalactic robotic designs. See how solar power drives the motor forcing these 3 robots to make different movements. If it's a cloudy day, then have some indoor fun and use a 50W halogen light. Projects include a tank, robot and a scorpion.

• Suitable for ages 10+

**6-in-1 Solar Educational Kit**
**KJ-8926 $14.50 plus postage & packing**
Build any one of six different projects from the parts in the kit. No tools, soldering or glue required. All the parts snap together with spring terminals for the wiring. The instructions are excellent with extremely clear illustrations detailing every step. The finished projects are solar powered, but can also be powered by the light from a household 50W halogen light.

Projects:
• Windmill
• Car
• Dog
• Plane
• Airboat
• Revolving Plane

Suitable for ages 10+

**Solar Powered Grasshopper Kit**
**GT-3751 $5.00 plus postage & packing**
Unleash the biblical wrath of Yahweh and wreak a horrible pestilence on thine enemies. Of course you might need to buy a few thousand, but think how good you'll be at building them!

Recommended for ages 8+

## SD/MMC CARD WEBSERVER IN A BOX

**KC-5489 $52.25 plus postage & packing**
Host your own website on a common SD/MMC card with this compact Web server In a Box (WIB). Connecting to the Internet via your modem/router, it features inbuilt HTTP server, FTP server, SMTP email client, dynamic DNS client, RS232 serial port, four digital outputs and four analogue inputs. Requires a SD memory card, some SMD soldering and a 6-9VDC adaptor. Kit includes PCB, case and electronic components.

• PCB: 123 x 74mm

## 45 SECOND VOICE RECORDER MODULE

**KC-5454 $25.50 plus postage & packing**
This kit has been improved and can now be set up easily to record two, four or eight different messages for random-access playback or a single message for 'tape mode' playback. Also, it now provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9-14V DC. Supplied with silk screened and solder masked PCB and all electronic components.

• PCB: 120 x 58mm

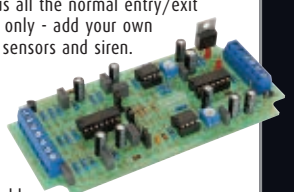
## 4 CHANNEL VERSATILE MIXER KIT

**KC-5448 $57.50 plus postage & packing**
This is an improved version of our popular guitar mixer kit and has a number of enhancements that make it even more versatile. The input sensitivity of each of the four channels is adjustable from a few millivolts to over 1V, so you plug in a range of input signals from a microphone to a line level signal from a CD player etc. A headphone amplifier circuit is included for monitoring purposes. A three stage EQ makes this is a very versatile mixer that will operate from 12VDC, 45mA. Kit includes case, PCB with overlay and all electronic components.

## SOLAR POWERED SHED ALARM KIT

**KC-5494 $17.50 plus postage & packing**
A lot of valuable items are stored in sheds or locations without access to mains power - a boat on a mooring, for example. What you need is a simple solar powered alarm that works with a variety of sensors - just what this kit does. It has 3 inputs, plus all the normal entry/exit delay etc. Short form kit only - add your own solar panel, SLA battery, sensors and siren.

Supply voltage: 12VDC
Current: 3mA during exit delay; 500µA with PIR connected
Exit delay: 22 seconds
Entry delay: 5-30s adjustable
Alarm period: 25s to 2.5minutes adjustable



## CLOCK WATCHERS CLOCK KIT WITH BLUE LEDS

**KC-5416 $109.75 plus postage & packing**
This fascinating unit consists of an AVR driven clock circuit, and produces a dazzling display with 60 blue LEDs around the perimeter. It looks amazing, and can be seen in action on our website. Kit supplied with double sided silk screened plated through hole PCB and all board components as well as the special clock housing.

Also available Clock Watchers Clock Kit KC-5404 $75.00

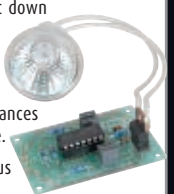
## LOW COST PROGRAMMABLE INTERVAL TIMER

**KC-5464 $20.50 plus postage & packing**
Here's a new and completely updated version of the very popular low cost 12VDC electronic timer. It is link programmed for either a single ON, or continuous ON/OFF cycling for up to 48 on/off time periods. Selectable periods are from 1 to 80 seconds, minutes, or hours and it can be restarted at any time. Kit includes PCB and all specified electronic components.

• PCB: 102 x 42mm

## FLICKERING FLAME LIGHTING

**KC-5234 $10.00 plus postage & packing**
This lighting effect uses a single 20 watt halogen lamp (the same as those used for domestic down lights) to mimic its namesake. Mounted on a compact PCB, it operates from 12VDC and uses just a handful of readily available components. Use it for stage performances or for unique lighting effects at home.



• Includes 20W halogen lamp, PCB plus electronic components
• Now includes SL-2735 $2.50 ceramic base

## KIT OF THE MONTH

new

**Ultrasonic Antifouling System For Boats**
**KC-5498 $124.50 plus postage & packing**
Many of you know that you can buy £1 - 4,000 imported marine growth electronic antifouling systems. Jaycar, with Silicon Chip have developed a similar system based on this technology and information in the public domain. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in sturdy polyurethane housings. By building yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer , potting and gluing components and housings. Only one transducer kit is needed for boats up to 32ft. Basically all parts supplied in the project kit including wiring.

• 12VDC
• Suitable for power or sail
• Could be powered by a solar panel/wind generator
• Price includes epoxies
• For more details visit our website www.jaycarelectronics.co.uk

MORE INFO AVAILABLE ONLINE

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|---|---|
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Max weight 12lb (5kg).
Heavier parcels POA.
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Jaycar Electronics

BY FRED EADY

# Still Rockin' the microSD Card

**It took a while, but paper punch cards finally bit the dust. Good old RS-232 is in the rocking chair, as well. These days, thanks to the microcontroller industries' hardware refinements and ready-to-run library code, putting a USB portal online is just as easy as building an RS-232 interface.**

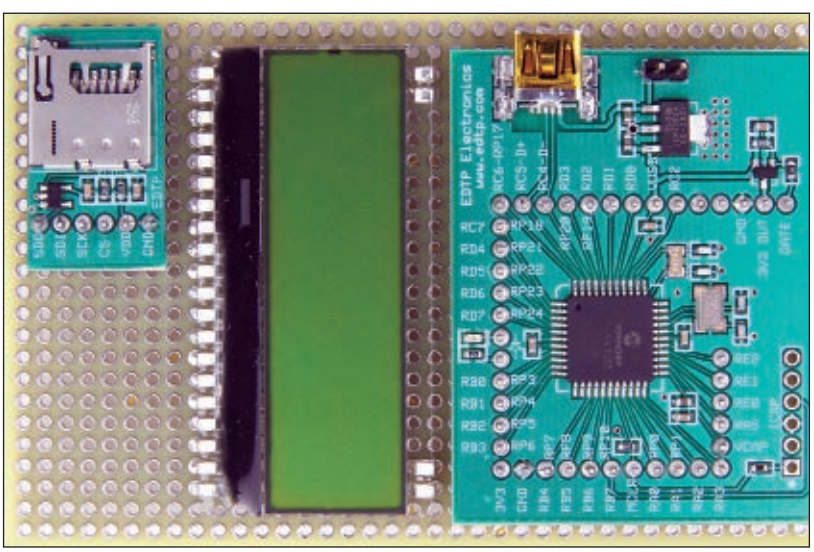
**The very first embedded computing devices wielded four bits. After the dust settled, eight-bit devices proved superior. Despite the emergence of multifaceted 16- and 32-bit microcontrollers, eight-bit microcontrollers are still a viable and powerful embedded control platform. If you had time to join us last month, you'll recall that we took a look at an eight-bit microcontroller capable of communicating with SPI, I²C, RS-232, and USB capable external devices. That particular eight-bit microcontroller used the SPI protocol to enhance its data storage capability via a microSD card.**

## EIGHT BITS IS STILL A BYTE

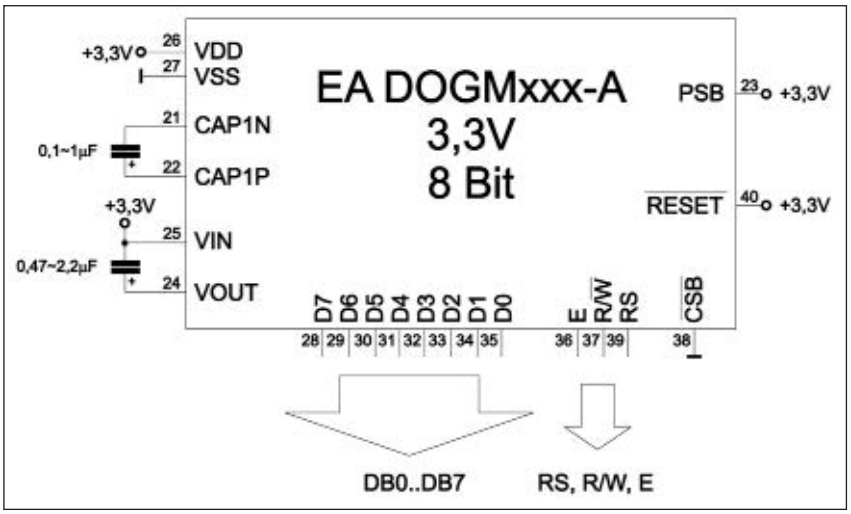
Eight-bit microcontrollers still pack a punch. The PIC18F46J50 we discussed last month is a very capable eight-bit embedded computing platform. However, with the Microchip bootloader code falling into a little less than half of the PIC18F46J50's program Flash, any bootloader application based on this PIC will have to reside within 34K or less of program Flash.

Many of the past Design Cycle projects have been based on the PIC18LF4620 and its relatives. The PIC18F46J50 just happens to be a USB-enabled PIC18LF4620 with peripheral pin select. This microcontroller we will walk around here is yet another enhanced version of the PIC18LF4620.

The PIC18F47J53 is well suited for use with the microSD card in a bootloader application. With the bootloader application loaded in program Flash, the PIC18F47J53 can still offer about 98K of program Flash for the user's application. If power conservation is a factor, the PIC18F47J53 can fall into a deep sleep while maintaining the correct time via its on-chip real time clock calendar subsystem. The PIC18F47J53 is a 3.3 volt part that is designed to easily interface to external 5.0 volt peripherals. All of the PIC18F47J53 I/O pins that are associated with communication protocols are 5.0 volt tolerant. The PIC18F47J53's parallel master port pins are also 5.0 volt tolerant. Basically, the PIC18F47J53 is a



■ PHOTO 1. The USCM-47J53 is a resource-enhanced USCM-46J50 that is intended to be placed in microSD card applications that need more program Flash. The USCM-47J53 also sports a 3.3 volt EA DOGM162L-A LCD module and a MOSFET power switch.




■ FIGURE 1. The active-low RESET line can be tied logically high or controlled via a microcontroller I/O pin. Otherwise, all of the standard eight-bit controls and data lines are offered to the user.

deep-sleeping, 128K program Flash version of the PIC18F46J50.

## DESIGNING THE USCM-47J53

If you had the opportunity to join in last month's Design Cycle discussion, you already know that *USCM* is short for Universal Storage Control Module. In our current situation, the storage comes in the form of a microSD card and the *Control Module* is based on the PIC18F47J53. Although the PIC18F46J50 and PIC18F47J53 are kissing cousins, the USCM-47J53 differs from last month's USCM-46J50 in a number of ways. Let's analyze the USCM-47J53 hardware suite that lies under the lens in **Photo 1,** beginning with a very different type of LCD.

## THE EA DOGM162L-A

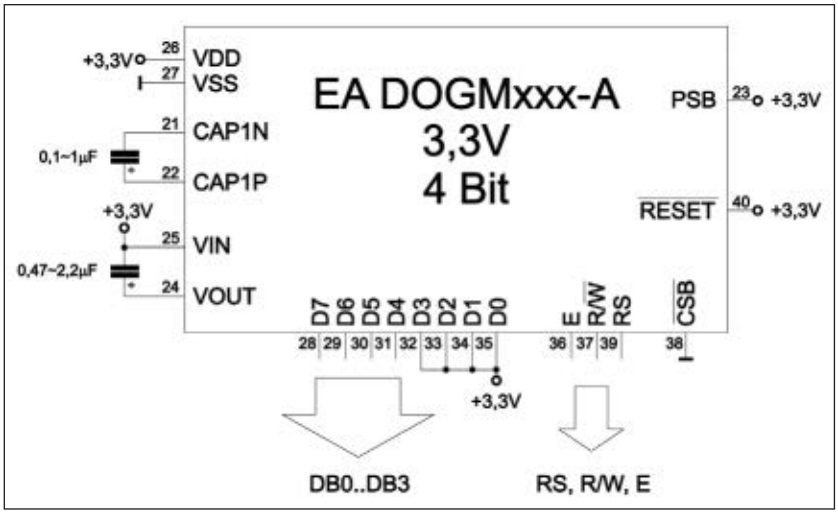
I've got a box full of standard LCD modules that I pull from for specific Design Cycle projects. Despite the differing number of rows and columns associated with each of my LCD modules, every module in the box has one common factor: They all require a 5.0 volt power source.

They still sell 5.0 volt voltage regulators. So, the good old TTL logic levels most of us grew up with are still valid. However, the PIC18F47J53 and many other modern low power microcontrollers feed on 3.3 volt power. We get away with driving the inputs of a 5.0 volt LCD with a 3.3 volt microcontroller because +3.3 volts is good enough to rate as a logical TTL high.

Another common trait of my box full of LCD modules is the way they are driven. If you have plenty of microcontroller I/O pins available to you, you can lash up all eight of the LCD module's data I/O pins, plus the three control inputs. The alternate method of driving a standard LCD module is to push four bits at a time into the LCD controller. The four-bit method requires only seven of the host microcontroller's I/O pins. If you opt not to read the LCD's status or internal display memory, you can save one more microcontroller I/O pin by tying the R/W pin logically low which will only allow writes to the LCD module. *Fred Eady's First Law of Embedded Computing* — which states that "Nothing is Free" — applies to each pin-saving LCD configuration. Extra data entry cycles are required to use four-bit mode and you lose the ability to read the LCD status and resources by tying the LCD module's R/W pin logically low. In addition, the loss of the ability to read the LCD module's Busy Flag forces the designer/programmer to time the LCD accesses.

The EA DOGM162L-A is based on the Sitronix ST7036. I don't know about you, but along with the 7805 5.0 volt regulator, I grew up with LCD modules based on the HD44780. So, it seems that all of those tried and true HD44780 firmware routines look like they will be falling off of the bench if we switch to the EA DOGM162L-A. A quick look at the very first page of the ST7036 datasheet vindicates the EA DOGM162L-A as the ST7036 is HD44780 instruction set compatible.

In addition to being able to speak HD44780, the EA DOGM162L-A can operate with power supply voltages between 2.7 and 5.5 volts. To make the EA DOGM162L-A even more HD44780 friendly, all of the standard LCD module eight-bit and four-bit parallel drive methods are supported by the EA DOGM162L-A with the addition of a




■ FIGURE 2. In that the EA DOGM162L-A is being powered by a 3.3 volt power source, the boost capacitors are present here, as well. The four-bit data path is identical to that of an HD44780-based LCD module.

SPI-based four-wire serial mode. The 3.3 volt trick that the EA DOGM162L-A performs is made possible by a pair of capacitors tied to an internal voltage boost circuit.

The EA DOGM162L-A displays dark green on yellow/green and is not capable of being backlit. Other LCD modules in the EA DOGMxxxx-x family require a backlight or can optionally be backlit. Like other aspects of the EA DOGMxxx-x LCD family, the method of backlighting the LCD modules is very clever. Instead of building in a backlight, the backlight simply clips to the LCD module and the backlight/LCD assembly is mounted as a unit. Six different backlight colors can be selected, depending on the LCD module that is in use.

The EA DOGM162L-A mounted on our USCM-47J53 is a 2 x 16 character LCD. Character height is 5.7 mm. **Figure 1** is a schematic representation of the EA DOGM162L-A configured for eight-bit parallel operation. The active-low CSB (Chip Select) is tied low as there is no need to "select" the EA DOGM162L-A when it owns all of the data and control resources. The same chip select logic holds true for the four-bit EA DOGM162L-A configuration depicted in **Figure 2**. The SPI configuration is capacitor boosted just like the parallel configurations. However, note that the EA DOGM162L-A's PSB (Interface Selection) pin is tied low which forces its internals into serial mode. Now that the EA DOGM162L-A is an SPI slave device, it must be able to be selected. Recall that the microSD card is also a SPI slave device. In addition to being selectable, the active-low CSB signal resets the EA DOGM162L-A's internal shift register and counter on its falling edge.

Most all of you that have used standard HD44780-based LCD modules are familiar with the eight-bit and four-bit parallel modes. So, let's strike out and configure our EA DOGM162L-A for SPI operation. To successfully use the EA DOGM162L-A in our USCM-47J53's 3.3 volt system, we have an engineering decision to make. In **Figures 1**, **2**, and **3**, the capacitor value for the CAP1P/CAP1N pin pair is specified as 0.1 µF to 1.0 µF. The ST7036 datasheet tells us that the range for the CAP1P/CAP1N pin pair is 0.1 µF to 4.7 µF. As a starting point, we'll install 1.0 µF ceramic capacitors at both the VIN/VOUT and CAP1P/CAP1N positions.

Although the EA DOGM162L-A's feature set is unique, it can't operate as a stand-alone electronic device. The EA DOGM162L-A's data input and control signals must be fed from the data stores of a microcontroller.

## THE USCM-47J53 MAIN HARDWARE

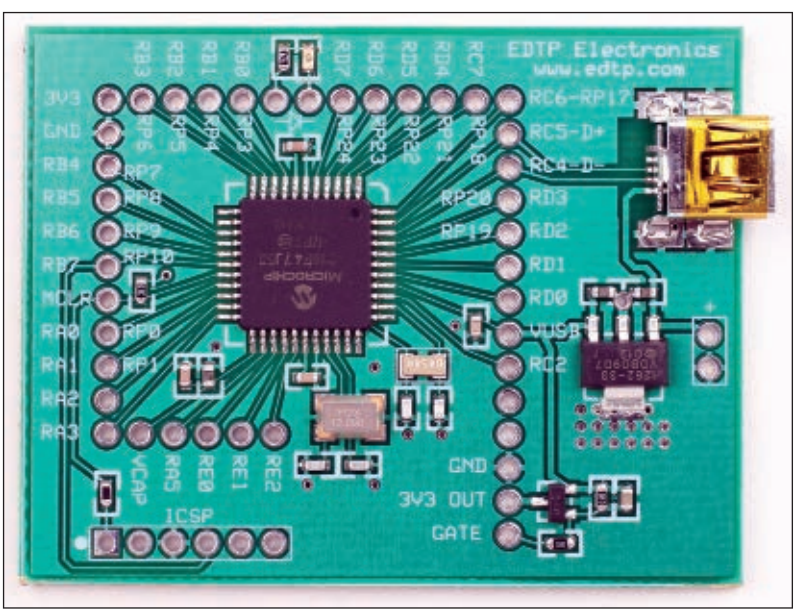
The PIC18F47J53 is a very robust eight-bit microcontroller. The intent of the USCM-47J53 is to provide you with a simple yet powerful microcontroller platform for your particular application. Everything the PIC18F47J53 needs for basic operation is mounted on the USCM-47J53 printed circuit board shown in **Photo 2**.

The USCM-47J53 is ideal for use as a timed-operation-high-storage-capacity embedded computing device. The PIC18F47J53 supports the Microchip microSD card library routines which provide standard FAT file system operations that can be used with the USCM-47J53's microSD card hardware.

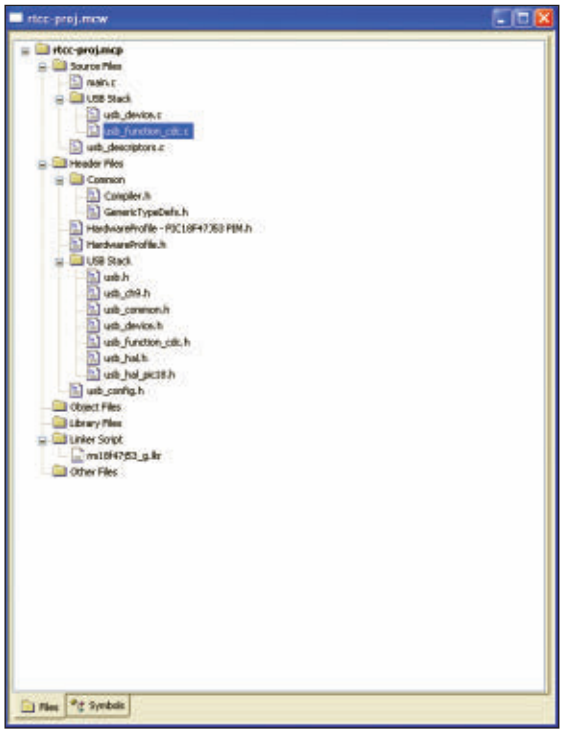
A hardware real time clock calendar (RTCC) provides precise time of day data with optional alarm and interrupt events. The USCM-47J53 is equipped with a 32.768 kHz clock crystal mounted across the TIMER1 oscillator pins. The 32.768 kHz crystal in conjunction with TIMER1 provides a precise time base for the PIC18F47J53's RTCC hardware.

USB is the primary medium used by the USCM-47J53 to communicate with the outside world. The USB portal also provides raw power for the PIC18F47J53, the EDTP microSD card interface, and EA DOGM162L-A LCD. However, you are not limited to using USB resources as all of the PIC18F47J53's SPI, I²C, parallel, and serial communications modules are available to you via the I/O header pins. In the absence of a USB connection, an external 5.0 volt power source can be used to power the USCM-47J53 and its peripherals.

A DMP2123L P-channel MOSFET has been added to the USCM-47J53 design. By connecting the DMP2123L's gate to a PIC18F47J53 I/O pin of your choice, the DMP2123L MOSFET can be used to switch +3.3 volts to peripheral devices under program control. If the RTCC is not one of your design points, the 32.768 kHz crystal and its associated load capacitors can be eliminated from the design which frees up the PWM output available at I/O pin RC0. The PWM signal can be used to drive the DMP2123L and provide a soft-start function that will limit the inrush current drawn from the host USB portal. The idea behind limiting inrush current is to keep the initial USB




■ PHOTO 2. Thanks to the Microchip Application Libraries, the USCM-47J53 is as easy to program as it is to build.

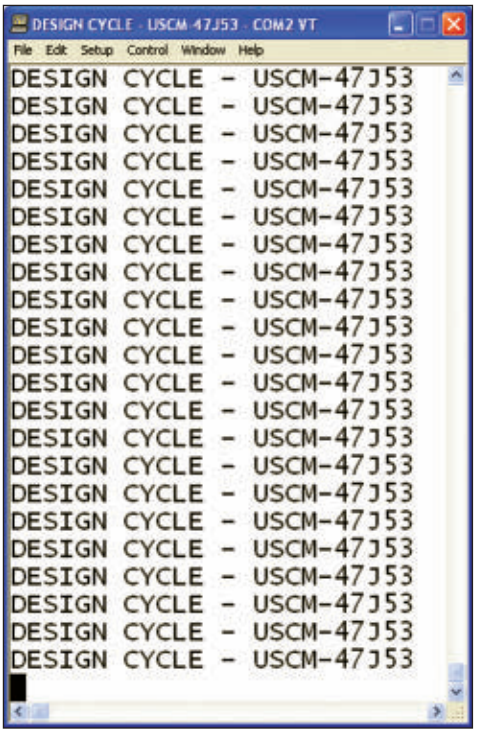


■ SCREENSHOT 1. Once you get the feel of what files are needed, the coding and realization of the project comes a bit easier. The USB stack is minimal and, as you can see, the star of the show is the *usb_function_cdc.c* file which contains most of the functions used in the *main.c* application source.

current draw within the published USB specifications. If your design needs to adhere to the USB specifications in this area, consult the *PIC18F Starter Kit User's Guide* (Microchip document DS51852A) for more detail.

Unless you're taking advantage of Microchip's factory programming service, your brand new PIC18F47J53 will emerge from its antistatic packaging as dumb as a rock with plated pins. In our case, that's a good thing as our USCM-47J53 has a PICkit3-compatible ICSP programming and debugging portal.

I'm all for super simple and built-in debugging tools. The LED falls into that category. So, I splurged and added a free-floating blue LED with an associated 470Ω current-limiting resistor to the USCM-47J53 design. Normally, the RS-232 portal is the most powerful built-in debugging tool available. However, there is no RS-232 support hardware designed into the USCM-47J53. The closest thing we have to an RS-232 portal is a miniature USB connector and some really tricky firmware.




■ SCREENSHOT 2. The Tera Term Pro terminal emulator and the PIC18F47J53's USB portal make for a cheap and powerful debugging tool.

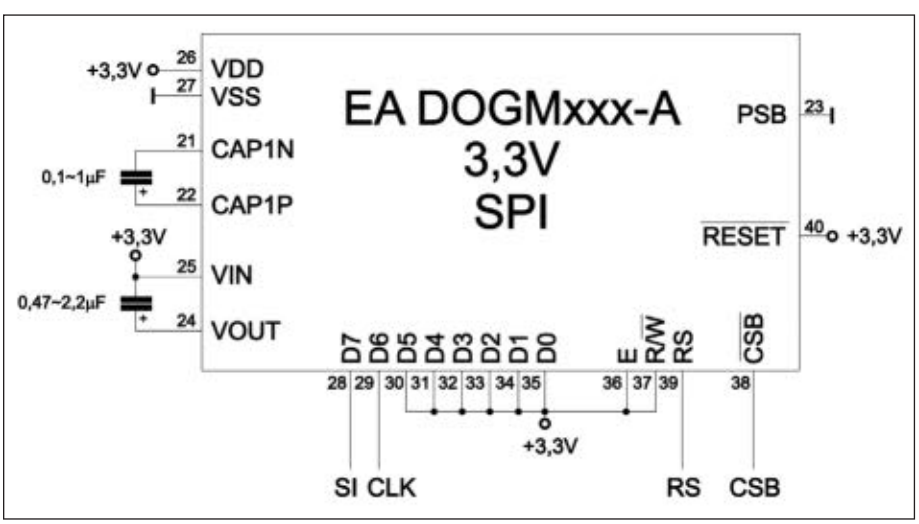
## USB PORTAL FUNCTIONAL TEST

The ability to implement an embedded USB portal with only a mini-B connector and a couple of printed circuit board traces is one of the reasons the PIC18F47J53 was selected to host the USCM-47J53. So, let's establish a built-in serial debugging tool and test the USCM-47J53's USB portal at the same time.

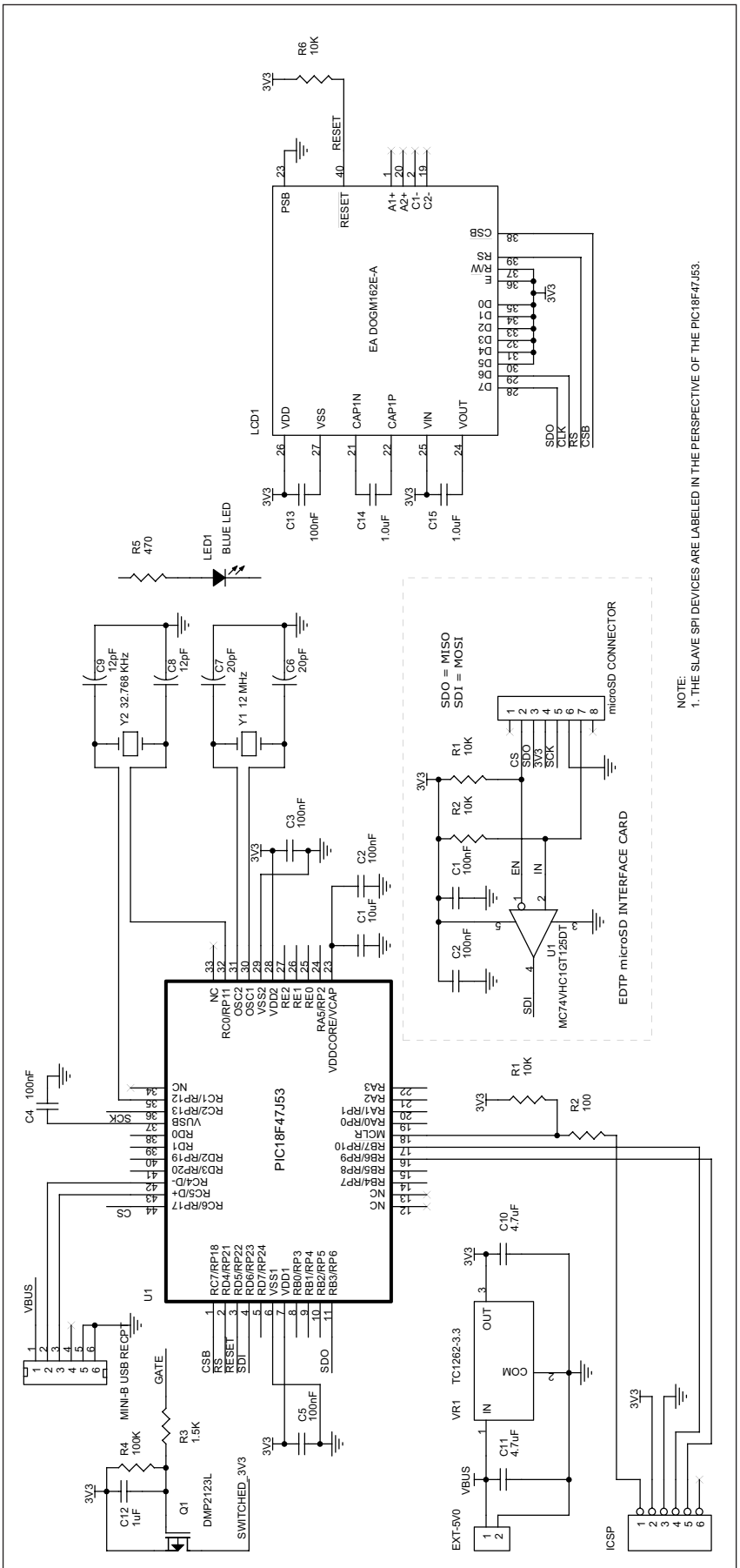
I used bits and pieces of existing Microchip Solutions library projects to put together a small USB project to exercise the PIC18F47J53's USB port. Since the idea is to replace the functionality of an RS-232 port with a mini-B equipped USB portal, my little USB project is based on a CDC (Communications Device Class) template. All of the project files are revealed in **Screenshot 1**.

The *HardwareProfile – PIC18F47J53 PIM.h* file uses C *#define* statements to associate switches, LEDs, and other peripheral devices to the PIC18F47J53's I/O resources. Since our USCM-47J53 design is devoid of preplanned LEDs and switches, the associations and resultant macros have no direct effect on our test application. However, there are a couple of lines of code within the *HardwareProfile – PIC18F47J53 PIM.h* file we need:

```
#define CLOCK_FREQ 48000000
#define GetSystemClock() CLOCK_FREQ
```




■ FIGURE 3. Note that the EA DOGM162L-A SPI configuration is also boosted with the external capacitor pair. The PSB line is tied logically low to enable an input only serial mode.




■ SCHEMATIC 1. This is almost as bare bones as this design can get. We can trim more fat by eliminating the crystals, their load capacitors, and the voltage regulator circuitry.

Our work will be performed within the *ProcessIO* function which resides in the *main.c* project file. Before we write our test code, we need to place an entry in the Variables area of the *main.c* file:

```
unsigned char
nvdata[CDC_DATA_OUT_EP_SIZE];
```

The CDC_DATA_OUT_EP_SIZE value is located in the *usb_config.h* file which is also part of our project:

```
#define CDC_DATA_OUT_EP_SIZE     64
```

With a little help from the *usb_function_cdc.c* file, we can now write our test code:

```
    if(USBUSARTIsTxTrfReady())
{
    char nvdata[] = "DESIGN CYCLE -
    USCM-47J53\r\n";
    putsUSBUSART(nvdata);
}
```

The *putsUSBUSART* function resides within the *usb_function_cdc.c* file. Here's a quote from the *putsUSBUSART* function description header:

```
  Summary:
    putsUSBUSART writes a string of
data to the USB including the null
character. Use this version, 'puts',
to transfer data from a RAM buffer.
```

Before we called upon the *putsUSBUSART*, we allocated a 64-byte buffer called *nvdata*. Once the *nvdata* buffer was allocated, we loaded *nvdata* with a null-terminated string. The call to the *putsUSBUSART* function produced the results you see in the Tera Term Pro terminal emulator session captured in **Screenshot 2**. To allow you to see everything associated with our little bit of test code, I've included the entire project in the download package.

## THE USCM-47J53 SPI PORTAL

If we desire to store and read data using the microSD card, we must construct the base for a SPI portal. Likewise, if we wish to view messages via the EA DOGM162L-A — which we've configured in SPI mode — a SPI

■ FIGURE 4. This is the peripheral pin select output pin map. Basically, I/O pins in the peripheral pin select system are assigned the function associated with the Output Function Number.

| Function | Output Function Number[1] | Output Name |
|---|---|---|
| NULL | 0 | NULL[2] |
| C1OUT | 1 | Comparator 1 Output |
| C2OUT | 2 | Comparator 2 Output |
| C3OUT | 3 | Comparator 3 Output |
| TX2/CK2 | 6 | EUSART2 Asynchronous Transmit/Asynchronous Clock Output |
| DT2 | 7 | EUSART2 Synchronous Transmit |
| SDO2 | 10 | SPI2 Data Output |
| SCK2 | 11 | SPI2 Clock Output |
| SSDMA | 12 | SPI DMA Slave Select |
| ULPOUT | 13 | Ultra Low-Power Wake-up Event |
| CCP1/P1A | 14 | ECCP1 Compare or PWM Output Channel A |
| P1B | 15 | ECCP1 Enhanced PWM Output, Channel B |
| P1C | 16 | ECCP1 Enhanced PWM Output, Channel C |
| P1D | 17 | ECCP1 Enhanced PWM Output, Channel D |
| CCP2/P2A | 18 | ECCP2 Compare or PWM Output |
| P2B | 19 | ECCP2 Enhanced PWM Output, Channel B |
| P2C | 20 | ECCP2 Enhanced PWM Output, Channel C |
| P2D | 21 | ECCP2 Enhanced PWM Output, Channel D |
| CCP3/P3A | 22 | ECCP3 Compare or PWM Output |
| P3B | 23 | ECCP3 Enhanced PWM Output, Channel B |
| P3C | 24 | ECCP3 Enhanced PWM Output, Channel C |
| P3D | 25 | ECCP3 Enhanced PWM Output, Channel D |

portal is essential.

To build our SPI portal, we must call upon the PIC18F47J53's peripheral pin select feature. A typical host SPI portal consists of an SDO pin, an SDI pin, and an SCK pin. If more than one SPI slave device is to be accessed by the SPI master device, a fourth pin is designated by the programmer to select a slave SPI device. When you reference the SPI portal in **Schematic 1**, keep in mind that the PIC18F47J53 SPI I/O pins are true with respect to the PIC18F47J53. That is, the SDO is actually the PIC18F47J53's SPI output pin and the SDI is really the PIC18F47J53's SPI portal input line. Again, I must use the language that makes it clear to me and hopefully clear for you. From the PIC18F47J53's perspective, consider the PIC18F47J53's SDO pin as Master Out Slave In (MOSI). With that, the PIC18F47J53's SDI pin becomes Master In Slave Out (MISO). The SPI lines of the slave devices are labeled in **Schematic 1** from the PIC18F47J53's perspective. Thus, the SPI slave device inputs are connected to the

■ FIGURE 5. This is the peripheral pin select input pin map. The register is tied to a function. The contents of the register assign the input function to the I/O pin that matches the value held in the register.

| Input Name | Function Name | Register | Configuration Bits |
|---|---|---|---|
| External Interrupt 1 | INT1 | RPINR1 | INTR1R<4:0> |
| External Interrupt 2 | INT2 | RPINR2 | INTR2R<4:0> |
| External Interrupt 3 | INT3 | RPINR3 | INTR3R<4:0> |
| Timer0 External Clock Input | T0CKI | RPINR4 | T0CKR<4:0> |
| Timer3 External Clock Input | T3CKI | RPINR6 | T3CKR<4:0> |
| Timer5 External Clock Input | T5CKI | RPINR15 | T5CKR<4:0> |
| Input Capture 1 | CCP1 | RPINR7 | IC1R<4:0> |
| Input Capture 2 | CCP2 | RPINR8 | IC2R<4:0> |
| Input Capture 3 | CCP3 | RPINR9 | IC3R<4:0> |
| Timer1 Gate Input | T1G | RPINR12 | T1GR<4:0> |
| Timer3 Gate Input | T3G | RPINR13 | T3GR<4:0> |
| Timer5 Gate Input | T5G | RPINR14 | T5GR<4:0> |
| EUSART2 Asynchronous Receive/Synchronous Receive | RX2/DT2 | RPINR16 | RX2DT2R<4:0> |
| EUSART2 Asynchronous Clock Input | CK2 | RPINR17 | CK2R<4:0> |
| SPI2 Data Input | SDI2 | RPINR21 | SDI2R<4:0> |
| SPI2 Clock Input | SCK2IN | RPINR22 | SCK2R<4:0> |
| SPI2 Slave Select Input | SS2IN | RPINR23 | SS2R<4:0> |
| PWM Fault Input | FLT0 | RPINR24 | OCFAR<4:0> |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master SPI output pin and the SPI slave device outputs connect to the master input pin. Now that you know which side of the road to stand on, let's go ahead and define our SPI portal:

```
//Initialize the SPI

   //  UnLock Registers
          EECON2 = 0x55;
          EECON2 = 0xAA;
          PPSCONbits.IOLOCK = 0;
   //  Unlock ends

   //  Pin Remapping
          RPOR6 = 10;
          //RP6 (RB3) as SDO2 (o/p)
          RPOR13 = 11;
          //RP13 (RC2) as SCK2 (o/p)
          RPINR21 = 23;
          //RP23 (RD6) as SDI2 (i/P)
//  Pin Remapping ends

//     Lock Registers
          EECON2 = 0x55;
          EECON2 = 0xAA;
          PPSCONbits.IOLOCK = 1;
//  Lock Registers ends
```

You will find the SPI portal construction code stashed in the *InitalizeSystem* function which is part of the *main.c* project file. To understand what went on while the peripheral pin select system was unlocked, take a look at **Figure 4**. *RPOR6* is actually a register that holds the value that determines which function I/O pin RP6 will perform. As you can see, the decimal 10 is loaded into RPOR6 which assigns the SPI2 Data Output function to RP6 which is really I/O pin RB3. You can see for yourself in **Figure 4** and **Schematic 1** what is happening with regard to register *RPOR13*.

The SPI portal input assignment works a bit differently. The *RPINR21* register is associated with the SPI2 Data Input function. To assign the SPI2 Data Input function to a particular I/O pin, we need only to load the *RPINR21* with the I/O pin numeric value. In our case, I/O pin RP23 (I/O pin RD6) becomes SDI2.

## LUCY ... YOU'VE GOT SOME CODING TO DO

The USCM-47J53 is all wired up according to **Schematic 1**. The task list for next month includes coding an SPI driver for the EA DOGM162L-A. We'll also put some digits into the PIC18F47J53's RTCC which we'll display using that EA DOGM162L-A driver. **NV**

### SOURCES

EDTP Electronics, Inc.
USCM-47J53
**www.edtp.com**

Electronic Assembly GmbH
EA DOGM162L-A
**www.lcd-module.com**

*Fred Eady can be reached at fred@edtp.com.*

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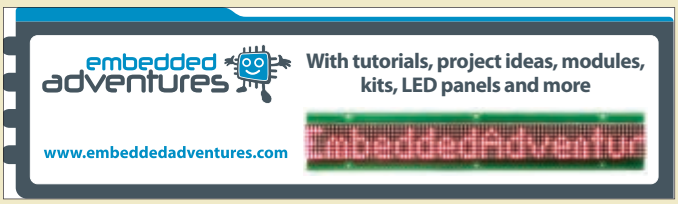


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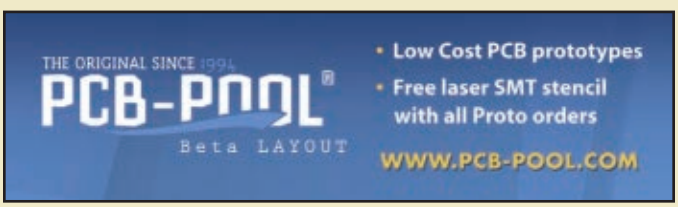


#29 SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

# SPI and the AVR Butterfly DataFlash

Follow along with this series! Joe's book & kits are available at www.nutsvolts.com

## Recap

Last month, we got a little shifty and learned about the 74HC595 and 74HC597 shift registers, wrote some software SPI (Serial Peripheral Interface) code, and built a new and improved (twice the eyes!) Cylon Eyes project. All that was in preparation for learning about hardware SPI so that we can use it to communicate with external Flash EEPROM memory. This month, we will create a library with hardware SPI functions. We will use the library with the built-in 4-Mbit DataFlash on the Atmel AVR Butterfly shown in **Figure 1**. The hardware used for the demonstration and the AVR Butterfly are available in the C Programming Book and Projects Kit combination that you can get from *Nuts & Volts*.

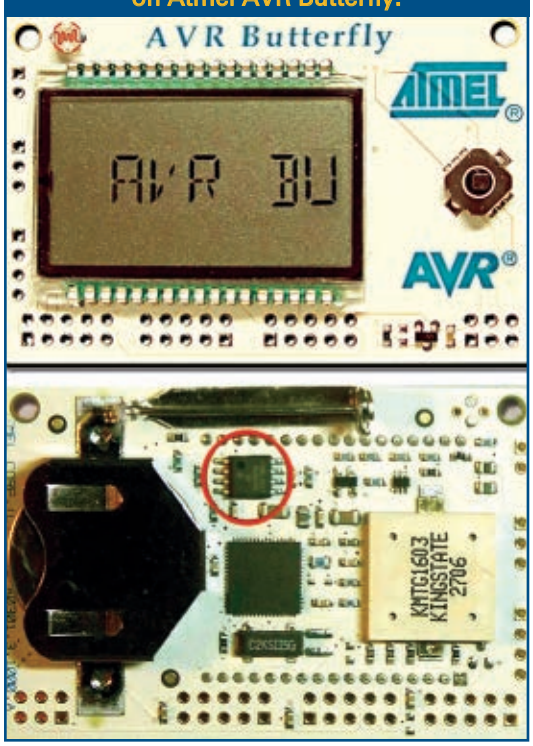
## AVR SPI Library

This month, we will create, document, and share a library of some AVR software and hardware SPI functions. To help keep things simple, we will only look at the SPI master mode – but the general principles apply to both master and slave modes so if you need your AVR to be a slave, you should be able to figure out how to implement this from the supplied code.

In Workshop 28, we learned how to bit-bang (you control each pin state) a software SPI bus so that we could theoretically use any available AVR 4 I/O pins to create an SPI link. We wrote the code to simplify the process of creating multiple SPI links and for compiling the code for multiple AVR devices (ATmega169, '328, '644). This month, we will extend that code and put it into a library of source code modules.

With software SPI, we are only limited in number of SPI devices by the number of available I/O pins. However, with the hardware SPI we have only a single SPI – but it requires that we generate our own slave select line, thus allowing us to have many slaves as shown in **Figure 2**. The slaves will only pay attention if their SS pin is held low, so by simply holding the other slave SS lines high, we get them to ignore us. We can also expand the number of slaves by daisy-chaining them as shown in **Figure 3**. The difference in using these two is that for the first, we have to select only one device at a time; in the second, we select all the devices at once, but must transfer all the data for each device at once (in the case shown, it would be three bytes).

■ FIGURE 1. Four-Mbit DataFlash on Atmel AVR Butterfly.




## Hardware SPI

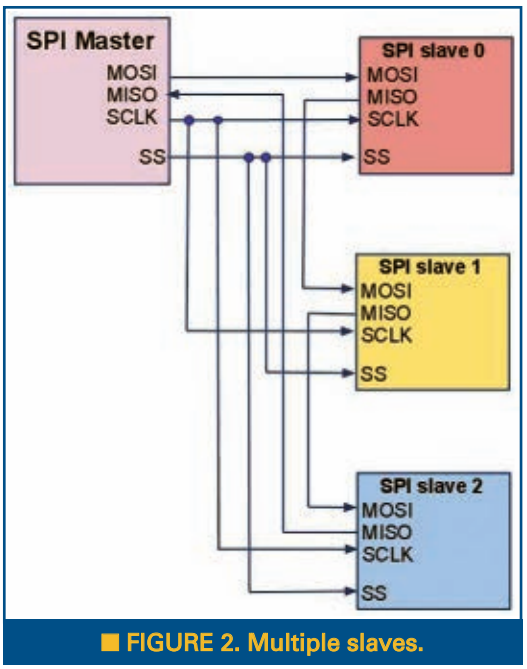
Even after all these years, I still cringe when I open the datasheets for a device. Atmel does as good a job as any, but it is still a daunting task to figure out among all the choices given, what subset to select for use in my particular application. SPI is one of the simplest peripherals that you can imagine, but look at the datasheet for any of the ATmegas we will use and skim the SPI section. Good grief! Lucky for you, though, I've selected a nice little subset that works well with the shift registers we looked at last month, and the DataFlash that is resident on the Butterfly.

Let me insert a special note here: The hardware slave select line /SS is not controlled by the hardware SPI, but **must be controlled by the user**. This confused me for a minute since it really doesn't make sense that they designate a /SS line when you can actually use any I/O line for /SS. But then it does make sense because if you are using the hardware SPI in slave mode, then you must use the

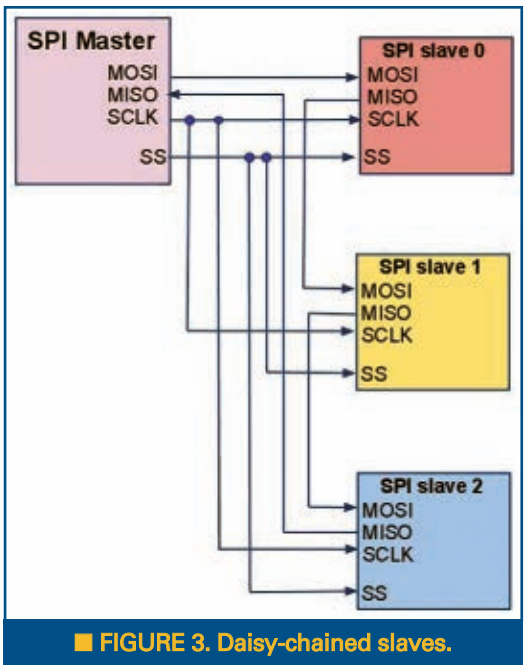
designated /SS line. We won't be doing the slave mode but at least now you know why it is provided.

## One Size Fits All — Yeah, Right ...

In order to make the library flexible, we are using some preprocessor commands that let us define items that we want compiled and ignore items we won't be using. We discussed doing this last month when we showed how we could write code that could be compiled for either the Butterfly, the Arduino, or the BeAVR40 by simply removing the comment '//' directive from a line:




■ FIGURE 2. Multiple slaves.




■ FIGURE 3. Daisy-chained slaves.

```
#define Butterfly
//#define Arduino
//#define BeAVR40
```

Later in the code:

```
#if defined (BeAVR40)
       // This section will be compiled only if
       // BeAVR40 is defined
#elif defined (Arduino)
       // This section will be compiled only if
       // Ardino is defined
#elif defined (Butterfly)
       // This section will be compiled only if
       // Butterfly is defined
#else
       // This line prints as an error if you
       // forget to define a board
       #error "No board defined"
#endif
```

While this is a very handy concept, it does tend to junk up the appearance of the code and make it harder to read. For our SPI library, we will allow the user to define multiple numbered SPI links such as SPI0, SPI1, ... SPIx. For each of these links, the user can define it as either software or hardware by defining either SPI_SOFT or SPI_HARD. I've written and tested the code for SPIO for both SPI_SOFT and SPI_HARD modes. If the user wants additional SPI links, then it is a 'simple' matter of copying the SPI0 code and changing the 0 to whatever number is desired, then going through and carefully assigning new I/O pins if you are using the software version or new hardware SPI pins if hardware. When you look at the code, it might take a few moments to figure out what I'm doing with all the defines, but bear with this since it will help create some very useful software concepts for making code easier to use with more than one device.

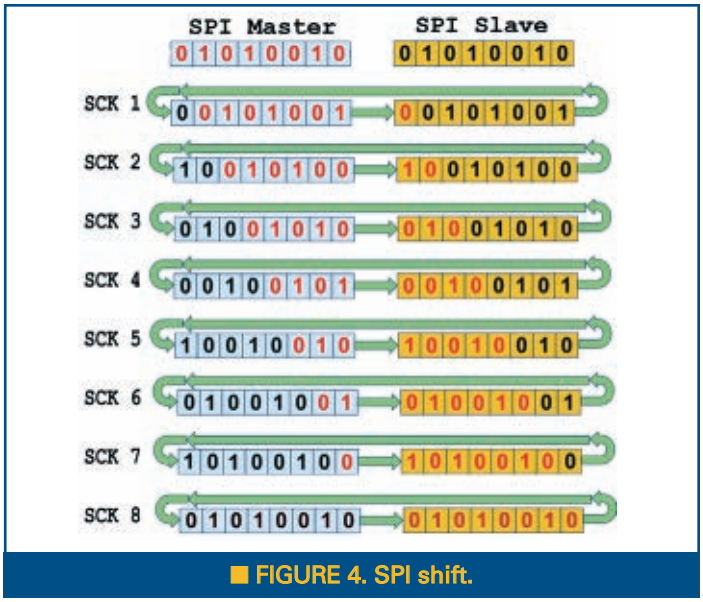
## Setting Up the SPI Registers

For similar reasons, we will use aliases for register and port names that vary between devices. For instance, the slave select data direction register is DDB4 for the Butterfly (ATmega169); DDB2 for the Arduino (ATmega328); and DDB6 for the BeAVR40 (ATmega644). By using the gcc compiler preprocessor, we can let it decide which one of these registers to use by using the #define preprocessor directive to define the device, then let the compiler select from the list of #ifdef – if defined – so that it uses the correct register for the device we are using. You can see all the SPI registers for each device in the source code in Workshop29.zip available from *Nuts & Volts*. Since we are using the Butterfly in this example, the registers are:

```
#if defined (Butterfly)
#define MOSI_HARDWARE_PIN PORTB2
#define MOSI_HARDWARE_DDR DDB2
#define MISO_HARDWARE_PIN PORTB3
#define MISO_HARDWARE_DDR DDB3
#define SCLK_HARDWARE_PIN PORTB1
#define SCLK_HARDWARE_DDR DDB1
#define SS_HARDWARE_PORT PORTB
#define SS_HARDWARE_PIN PORTB4
#define SS_HARDWARE_DDR DDB4
```

If we had hardwired (used the register name instead of the defined alias) these registers in the software, then if we built it first for the Butterfly and later wanted to port it to the Arduino board we'd have to hunt down every place where each of the nine registers differ and change it. The SPI is about the simplest peripheral on an AVR so, again, this 'one size fits all' technique becomes even more important for creating libraries that you want to use with more than one AVR device.

An example of this usage is shown next in the spi0_hard_init_master() function. Since we have gone to the trouble of providing aliases such as MISO_HARDWARE_PIN, we only have to change from Butterfly to Arduino one place in the header to convert the function from working on the Butterfly to the Arduino.




■ FIGURE 4. SPI shift.

```
void spi0_hard_init_master(void)
{
        PORTB |= (1<< MISO_HARDWARE_PIN) \
                        | (1<< MOSI_HARDWARE_PIN) \
                        | (1<< SCLK_HARDWARE_PIN) \
                        | (1<< SS_HARDWARE_PIN);

        //Set MOSI, SCK AND SS to outputs
        DDRB |= (1<< MOSI_HARDWARE_DDR) \
                        | (1<< SCLK_HARDWARE_DDR) \
                        | (1<< SS_HARDWARE_DDR);

        // Set Miso to input
        DDRB &= ~(1<<MISO_HARDWARE_DDR);

        // SPE - SPI Enable
        // MSTR - Master\Slave Select
        // SPR0 - Fosc/16
    SPCR = ( 1 << SPE ) | ( 1 << MSTR ) | ( 1
<< SPR0 );
}
```

## SPCR — SPI Control Register

There are also too many choices for the SPCR register. You'll have to carefully read the datasheet if you want your SPI to be different from this one. In our case, we chose to set the bits as follows:

- SPE – SPI Enable: A write to 1 enables the SPI.
- MSTR – Master/Slave Select: A write to 1 selects the master mode.
- SPR0: The clock bits default to 0 so setting this bit to 1 selects an SCLK rate of 1/16 the AVR oscillator speed. In our case, 16000000/16 = 1 MHz.

We just leave the other SPI control bits at their default 0 state which selects for the desired options.

## Using Our SPI Library

Using the SPI couldn't be simpler (or rather, I couldn't make it simpler). First, you select the device you are writing to by setting its slave select (/SS) pin low, then load the data you want to send into the SPDR (SPI Data Register), then wait for the SPIF flag in the SPSR to be set. Then, finally load the data received from the SPDR register. (Note that the data goes out of and into the same register — as shown in **Figure 4**.) This is shown in the spi_hard_master_rw8 function below:

```
// Simultaneously sends a byte to the slave
// and receives a byte from the slave
uint8_t spi0_hard_master_rw8(uint8_t to_slave)
{
        uint8_t from_slave;

        // select slave
        spi_hard_set_ss();

        // Put byte in SPI data register
        SPDR = to_slave;

        // Poll SPIF-flag until transfer complete
        while(!(SPSR & (1<<SPIF)));


        // Get the SPI data reg.
        from_slave = SPDR;

        // deselect slave
        spi_hard_clear_ss();

        //return it
        return from_slave;

}
```

Rather than go into a lot more detail about the SPI source code, I invite the reader to look at the two applications in this month's Workshop29.zip: one for Chaser Lights and one for testing the DataFlash.

## Atmel DataFlash

**Figure 5** is a block diagram of our DataFlash. The Atmel DataFlash family has from 1 to 128 Mbit (500 Kbyte to 16 Mbyte) SPI serial memory ICs that come in small packages and require only four pins for access. They use on-board SRAM, small page sizes, and flexible opcodes to facilitate data access. Atmel claims this is the 'world's number one selling serial interface Flash family' and that they make the 'world's fastest serial Flash' (go to **www.Atmel.com** for more exciting marketing hyperbole).

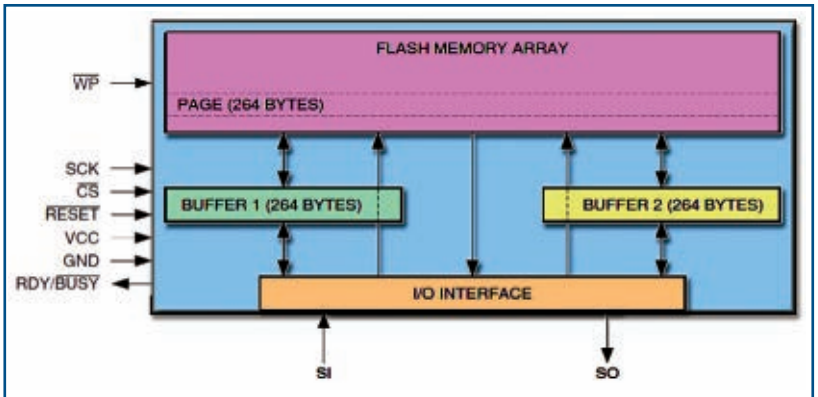
With 100K guaranteed write cycles, it is unlikely that we are going to wear out the Butterfly DataFlash, but please note that for serious — as in commercial — use of the Atmel DataFlash you should carefully read the datasheets and get the Atmel DataFlash Sofware Suite (you have to ask them for it from Atmel) to increase a device's life span. Also, **to keep from killing it immediately** it is important to remember that on the AVR Butterfly the DataFlash is restricted to 2.7 to 3.6 volts, but the ATmega169 is rated up to 5.5 volts. So some folks use a five-volt supply and then fry their DataFlash. This kind of error is called: 'You din'a RTFM!'

The AT45DB041B has 26 opcode commands that control its actions. These commands provide a variety of functions but as usual we will only look at a useful subset of the myriad of possibilities. We will learn how to read the device status, read and write data to the 264-byte SRAM buffers, tell it to write a buffer to a Flash page, and tell it

to read a Flash page into a buffer.

## Talking to DataFlash

Much of the DataFlash low level software was adapted from the Martin Thomas gcc port of the original Butterfly software available at **www.siwawi.arubi.uni-kl.de/avr_projects/**. However, a lot has been changed to fit into my evolving coding style and we will use our SPI library.




■ FIGURE 5. DataFlash block diagram.

## Read the Status Register

The simplest thing we can do is read the DataFlash Status register. This is a relatively straightforward use of SPI. We send the opcode 0x57 for 'read the status register' to the DataFlash; then we send a dummy byte while reading the byte returned which is the status byte. **Figure 6** shows the bits in the status register. Bit 7: RDY/BUSY reads 1 if the device is ready to write a buffer page to a Flash page and 0 if it is busy. Bit 6: COMP is for the most recent Main Memory Page to Buffer Compare operation; it is 0 if they are the same and 1 if there is any difference. Bits 5–2 provide device memory size information. The lowest two bits aren't used.

Our df_read_status function reads the status register and uses the device information bits with a lookup table to determine the value of the df_page_bits and df_page_size variables that may be used in other functions.

```
uint8_t df_read_status (void)
{
        uint8_t result,index_copy;

        // Toggle SS to reset DataFlash command
        // decoder
        spi0_hard_SS();

        // Send opcode to read the status
        // register
        result = spi0_master_rw8(StatusReg);
        // Send a dummy byte to receive the
        // results
        result = spi0_master_rw8(0x00);

        // Get the size information
        index_copy = ((result & 0x38) >> 3);

        // Get the number of page address bits
        // from the lookup table
        df_page_bits = pgm_read_byte(&df_
        page_bits_array[index_copy]);
        // Get the size of the page (in bytes)
        df_page_size = pgm_read_word(&df_
        page_size_array[index_copy]);

        // Return the status register value
        return result;
}
```

```
void show_status()
{
        char status = 0;
        char array[] = {0,0,0,0,0,0,0,0,0,0,0};

        // Get the status
        status = df_read_status();

        uart_send_string("\rStatus:\r");
        show_bits(status);

        uart_send_string("\rdf_page_bits: ");
        itoa((int16_t)df_page_bits,array,10);
        uart_send_string(array);
        uart_send_string("\rdf_page_size: ");
        itoa((int16_t)df_page_size,array,10);
        uart_send_string(array);
        uart_send_byte('\r');
}
```

■ FIGURE 6. The DataFlash status register.

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| RDY/BUSY | COMP | 0 | 1 | 1 | 1 | X | X |

■ FIGURE 7. Output on Bray's Terminal.

## Test Read/Write Status Register and SRAM Buffers

For our first test, we will read the status register and show the bits in the status register, along with the value of the page bits and size variables.

The show_status() function sends out the following on our serial port:

```
Status:
10011100
>———<
df_page_bits: 9
df_page_size: 264
```

This tells us that since bit 7 is 1, the device is not busy, that it has nine page bits, and that each page is 264 bytes.

For testing the buffer read\writes, we use the DataFlash library functions df_buffer_write_string and df_buffer_read_string. These two functions are very similar so we will show only the write function.

The parameters are:

df_buffer_no - Select buffer 1 or 2.
df_int_page_adr - Selects Flash page address.
No_of_bytes – Sets number of bytes to be written.
*BufferPtr - Provides the address of the buffer for copy of bytes.

```
df_buffer_write_str (uint8_t df_buffer_no, \
uint16_t df_int_page_adr, \
uint16_t No_of_bytes, \
uint8_t *BufferPtr)
{
        uint16_t i;

        // Toggle slave select
        spi0_hard_SS();

        // Write to buffer 1
        if (1 == df_buffer_no) //write byte(s)
        to buffer 1
        {
                // Send buffer 1 opcode
                spi0_master_rw8(Buf1Write);
        }
        else if (2 == df_buffer_no)// Write to
        Buffer 2
        {
                // Send buffer 2 opcode
                spi0_master_rw8(Buf2Write);
        }

        //Send dummy
        spi0_master_rw8(0x00);
        // Send upper part of buffer address
        spi0_master_rw8((uint8_t)
        (df_int_page_adr>>8));
        // Send lower part of buffer address
        spi0_master_rw8((uint8_t)
        (df_int_page_adr));

        for( i=0; i<No_of_bytes; i++)
        {
                // Write byte pointed at by
                // *BufferPtr
                spi0_master_rw8(*(BufferPtr));
                // Point to next byte
                BufferPtr++;
        }
}
```

We test the buffer read\write with the buffer_test() function by using two arrays: one with "Hello, World!" and the other with "Goodbye ya'll." We first verify that these arrays show what they are supposed to, then we write the first array to buffer 1, read buffer 1 into the second array, and show them again to verify that the first array was sent to the buffer and then read back into the second array. Since we are running short on space we'll just show the results of these tests in **Figure 7**.

The code we've shown here should be enough to introduce the principles we used to create both the SPI hardware and the DataFlash libraries. We test these libraries in the DataFlashTest project in Workshop29.zip. We will use these libraries next month to create a Butterfly Data Logger.

Now for some good news: I'm finally moving into the 21st century and started a blog for Smiley's Workshop at: **http://smileymicros.com/blog**. As the title indicates, it will be mostly related to this column. But then again, who knows what kind of rants and tangents I might get off on. **NV**

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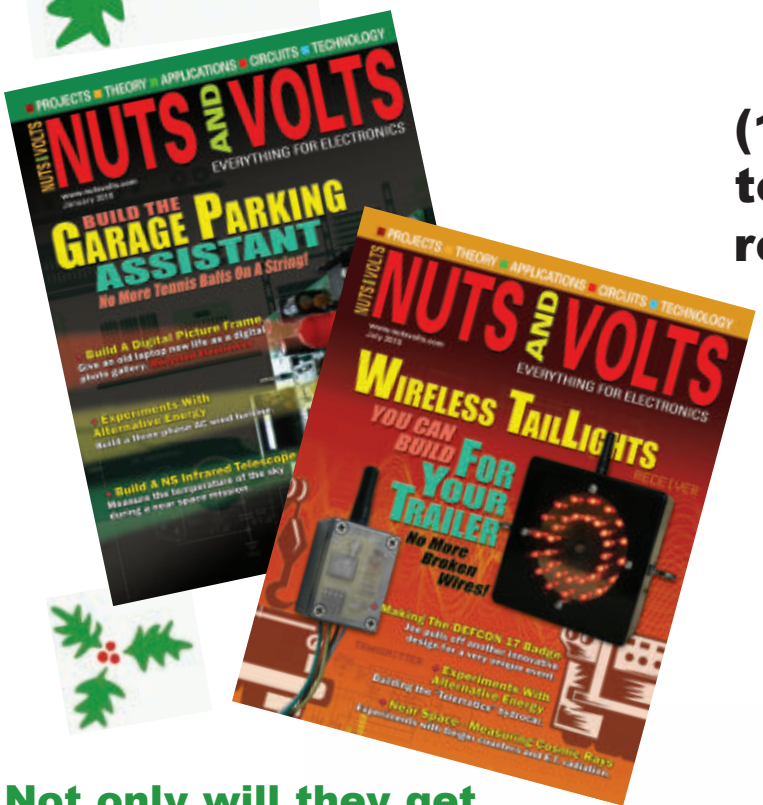


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BY LOUIS E. FRENZEL W5LEF

# 3G, 4G, SMARTPHONES, AND TABLETS: UPDATE ON THE MOBILE WIRELESS PRODUCTS WE ALL CRAVE

**Mobile products are all the rage. Today, everyone has a cell phone and many of you have already updated to a hot smartphone. Laptops are the best selling PCs and netbooks have expanded the mobile marketplace. Those of you on the cutting edge already have a tablet PC. That is good news for the cellular business. But do you know the technical details behind all those devices? Interesting stuff. If you are not up to date on the current and coming technology and the trends, here is an update.**

## SMARTPHONES FOR EVERYONE

Cell phones typically come in three categories: basic phones, feature phones, and smartphones. Basic phones are just what the name implies. They make phone calls and do texting, and that is about it. Feature phones are a bit more interesting as they make calls and do texting but also usually have a built-in camera and a Bluetooth headset, play games, and have an MP3 player or FM radio built in. Smartphones have all of the above plus have high speed data capability that gives them Internet access and email. They also feature music players, video play-back and record, and have extensive game capability. Most also have Wi-Fi 802.11 wireless LAN capability as a standard feature. The majority of smartphones have a GPS receiver with full navigation features. These phones are the Swiss army knife of the industry.

■ FIGURE 1. The Apple iPhone 4 — the smartphone of choice by consumers. With front and rear video cameras, it can make picture phone calls.

You already know who the main smartphone players are. BlackBerry is number one in this space as far as volume of phones is concerned (over 40% market share) but it's the Apple iPhone that gets all the attention. Their iPhone 4 in **Figure 1** is the top consumer smartphone with about 22% market share. Others with smartphones are Nokia, Samsung, Motorola (Droid), HTC (Evo), LG, and a few others. Palm, Garmin, and Google also tried their hand at smartphones but did not fare so well so have abandoned the market.

The basic trends are that most new phones are smartphones so the feature phone category is fading. Pretty soon there will probably be only two classes of cell phones: basic (including the feature phones) and smartphones. As smartphones come down in price and do a better job of accessing the Internet and playing video, they will no doubt come to dominate the market. People just love the fact that their phone is also a mobile Internet device with all that implies.

With regard to smartphone features, the trends are to have larger, higher resolution screens, faster data connections, and more video capability. Touch screens are now the predominant input technology although conventional keyboards are still a part of some of the higher volume phones (BlackBerry). Internet access and email are a given. TV is not far behind. It's actually available now in the form of FLO TV which is offered by AT&T and Verizon (but that is going away). Soon to come is standard digital TV in the US. The mobile/handset version of the American Standard Television Committee (ATSC) HD digital TV standard is now approved, and soon tuners will be available so that US broadcast TV can be received by cell phones and other mobile devices.

## 3G AND 4G ARE HERE

3G and 4G refer to the third and fourth generations of cell phone technology. The first generation was plain old analog FM. The second generation was digital phones that expanded the subscriber capacity of cellular networks. 3G is also digital but with a greater data capability. Data means text messages, Internet, email, video, and games, and any new thing that comes along. The minimum 3G data rate is 384 kbps but most 3G services offer high rates depending on the network, the technology, environmental conditions, and other factors but is typically several megabits per second (Mbps).

3G also defines the radio and access technologies. The world's most popular 3G technology is wideband CDMA (code division multiple access) offered by a majority of carriers worldwide. It is available in the US from AT&T and T-Mobile, as well as some of the smaller carriers. WCDMA provides a data rate to 2 Mbps. Most carriers have updated their 3G systems to a faster technology called high speed packet access (HSPA) that gives even faster rates to 7, 14, and 21 Mbps depending on the carrier's implementation.

The other predominant 3G technology is cdma2000. Also a form of CDMA but incompatible with WCDMA, this system is used by Sprint and Verizon. It works well and has various data capabilities up to many Mbps.

The fourth generation (4G) is just getting started. It essentially means faster data rates making it a better user experience for video, games, and Internet access by cell phone. The first 4G system to go online was Sprint and Clearwire with their WiMAX technology. This is a high speed wireless system that uses orthogonal frequency division multiplexing (OFDM). It easily provides many Mbps of data speed over a wide range. You can get it now from Sprint using the HTC Evo smartphone (see **Figure 2**). WiMAX is also available as a high speed wireless broadband connection at home from Clear — the Clearwire data service. It is an alternative to cable TV or DSL for Internet access in many areas around the US.

The primary 4G technology is called long term evolution (LTE). Similar to WiMAX, it also uses OFDM. All the major carriers are well on their way to evolving their systems to LTE. LTE promises 50 to 100 Mbps data rates under favorable conditions. MetroPCS in the US has just launched LTE, with Verizon not too far behind. AT&T and T-Mobile will no doubt implement LTE starting in 2011. Not too many LTE phones are available yet but many are in development. The Samsung Craft is the LTE phone used by MetroPCS subscribers, but more are on the way.

Upgrading a cellular network to 4G is a huge and expensive task. It will take time and a major capital investment. Look for 4G to come along gradually with service in the major cities first, then elsewhere over time. Cell phone base stations will need to be expanded and many will get new antenna systems to accommodate the multiple antenna technology in LTE referred to as multiple input multiple output (MIMO). In addition, the backhaul connections from the base stations to the main cellular office and switches are undergoing a major upgrade. The widely used slower T1 digital telephone lines are being replaced with faster fiber optic cable and high speed microwave links. Overall, it will take time but it has to be done as the backhaul is the last bottleneck in the system to handle the millions of fast cell phone connections.

## THE OPERATING SYSTEMS

A major feature of any personal computer is its operating system (OS). Most people have some form of Microsoft Windows like XP, Vista, or the new Windows 7. Apple users have their OS X version. A few hardy souls use Firefox or Chrome. In any case, the OS is a big deal as it affects how we use our PCs, laptops, or netbooks, and it determines what software we can run and the operations we can perform. The question is what does an OS have to do with a cell phone?

Most smartphones are so complex and have so many functions that they require an OS to manage all the memory and functions. Each of the main smartphone manufacturers has its own OS and it has become a big deal as it defines how the cell phones are used. Apple's iPhone OS is probably the benchmark for smartphones as it has established the operational modes with icons on a touch screen and other functions like swipe and zoom. BlackBerry has its own OS, as well. However, the OS that has emerged as the one to beat is Google's Android. It is essentially free and open software (except for patent licensing) that has been adopted by Samsung, HTC, Motorola, LG, and a few others. It may turn out to be the highest volume OS in use in another year or so.

Nokia — the highest volume cell phone manufacturer in the world — has used its own OS called Symbian. Until recently, it was the highest volume cell phone OS in the world. Now, Nokia has a new OS called MeeGo that is a joint development with Intel. It is used on their latest smartphone entry called the N8, shown in **Figure 3**.

So, where is Microsoft in all of this? Microsoft has had a cell phone OS from the beginning, but it has never been a dominant player. However, Microsoft is still trying. Their new Phone 7 OS for smartphones is now available and some phones are now available from Dell, Samsung, LG, and HTC with that OS. **Figure 4** shows the new HTC smartphone with Windows Phone 7. It remains to be seen how well it will stand up to the iPhone and Android OSs.

You don't have to worry about selecting an OS for your cell phone. It comes preinstalled and handles all the functions. And it defines how you use the phone, its ease, and convenience. You can update it with new versions later as they become available.

■ FIGURE 2. The HTC EVO is the first 4G cell phone. It uses the WiMAX OFDM wireless technology on Spint and Clearwire networks.

■ FIGURE 3. Nokia's new N8 smartphone. While not yet a hot item in the US, it is a worldwide hit.

■ FIGURE 4. The HTC Surround available from AT&T uses the Windows Phone 7 OS. Its user interface features configurable tiles instead of icons for a fresh new smartphone look.

## APPS

Some things that have really made the smartphone a hot item are the applications programs known as apps. These small but useful programs can be downloaded free or for a small fee, and provide a huge range of useful functions. Most of the apps are games but there are tons of others for news and weather, navigation, social networking, entertainment, finance, e-reading, and others. Apple dominates the apps area with over 200,000 apps but Google's Android OS has about 80,000 or so and is well on its way to more. Even Amazon is trying to get in on the coming Android apps growth spurt. RIM BlackBerry has 9,000+ apps and all the other phone manufacturers are working on their own apps programs like Nokia's Ovi program which claims 12,000 or more. There are few Microsoft apps but with the new OS, that will probably change.

## TABLETS — THE ULTIMATE MOBILE DEVICE

The recently introduced Apple iPad (**Figure 5**) is a huge success. Many millions have been sold and it is still a hot gift

idea today. (Who doesn't want one?) With more tablets available, there will be even more to come.

A tablet — also referred to as a slate — is not a cell phone and it is not a PC. It is a hybrid device somewhere in between. PCs have morphed to laptops to netbooks, and now the tablet is encroaching on that market. You can also think of the tablet as a smartphone with a larger screen. It does not make phone calls as such, but does in some forms contain a 3G cellular data connection, as well as its Wi-Fi wireless capability. It has all the other basic smartphone features too. It has Internet access, email, texting, still and video cameras, GPS, and serious video. Most are also e-book readers like Amazon's popular Kindle.

The idea of a tablet computer has been around for decades. Many have tried to make a small portable PC without the keyboard and big screen, but most have failed. The market was just not ready. A few specialized computers came out of it but nothing like the tablet trend of today.

Tablets will not kill off the laptop or netbook. Those will still be popular because they do have real keyboards and run office software (word processing, spreadsheets, Power Point, etc.) we all need access to on a regular basis. When you look at what the dominant use of a laptop or netbook is, you can see why a tablet might be a replacement for some people. That dominant application is Internet access, mail, and social networking with YouTube, Facebook, MySpace, video, and others. A tablet is ideal here with its larger touch screen, video features, and fast data connections via a 3G network or a nearby Wi-Fi hotspot. If you need to make a phone call, use your cellphone or possibly use Skype on the tablet.

While the hot tablet is the Apple iPad, there are others getting some attention. The Samsung Galaxy Tab is one. So are the tablets from Dell. RIM has their BlackBerry tablet called the PlayBook. It uses the popular RTOS QNX for its OS. It does not have built-in 3G service but has Wi-fi and Bluetooth, and can connect to a cellular network via a BlackBerry phone. More tablets are on the way from HP, Lenovo, Toshiba, and even Microsoft. It remains to be seen if they can beat Apple's iPad, but they certainly will try. **NV**

■ FIGURE 5. An Apple iPad with its 9.7 inch touch screen. It comes in Wi-Fi only or 3G plus Wi-Fi forms for wireless connectivity. The only thing it does not do is make phone calls.

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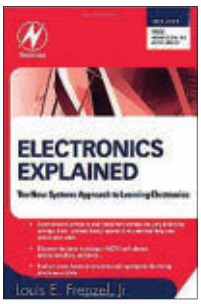


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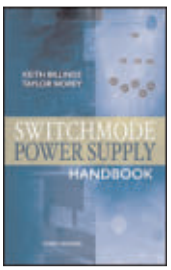


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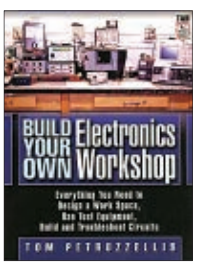


This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action -- building, testing, and troubleshooting systems. This great book has it all! And the best part is, it shows you how to build many pieces of equipment yourself and save money, big time!
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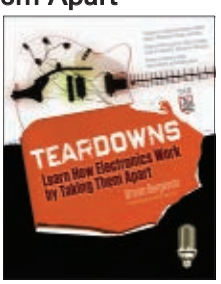
### Master and Command C for PIC MCUs
by Fred Eady

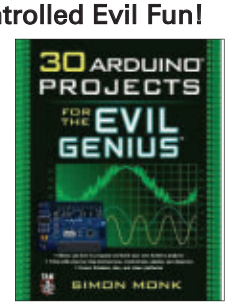
*Master and Command C for PIC MCU, Volume 1* aims to help readers get the most out of the Custom Computer Services (CCS) C compiler for PIC microcontrollers. The author describes some basic compiler operations that will help programmers, particularly those new to the craft create solid code that lends itself to easy debugging and testing. As Eady notes in his preface, a single built-in CCS compiler call output_bit can serve as a basic aid to let programmers know about the "health" of their PIC code.
**$14.95**

### TEARDOWNS
by Bryan Bergeron
**Learn How Electronics Work by Taking Them Apart**




Amp up your knowledge of electronics by deconstructing common devices and analyzing the revealed components and circuitry. *Teardowns: Learn How Electronics Work by Taking Them Apart* contains 14 projects that expose the inner workings of household appliances, workbench measuring instruments, and musical equipment. Discover how resistors, capacitors, sensors, transducers, and transistors function in real circuitry.
**Reg $24.95 Sale Price $21.95**

### 30 Arduino Projects for the Evil Genius
by Simon Monk
**30 Ways to Have Some Computer-Controlled Evil Fun!**




Using easy-to-find components and equipment, this do-it-yourself book explains how to attach an Arduino board to your computer, program it, and connect electronics to it to create fiendishly fun projects. The only limit is your imagination!
**$24.95**
**See special offers on this book!**

### Programming PICs in Basic
by Chuck Hellebuyck

If you wanted to learn how to program microcontrollers, then you've found the right book. Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the eight-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low-cost development tool called the CHIPAXE system and the BASIC software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an eight-pin PIC12F683 microcontroller. **$14.95**

### PICAXE Microcontroller Projects for the Evil Genius
by Ron Hackett

This wickedly inventive guide shows you how to program, build, and debug a variety of PICAXE microcontroller projects. *PICAXE Microcontroller Projects for the Evil Genius* gets you started with programming and I/O interfacing right away, and then shows you how to develop a master processor circuit.
**$24.95**
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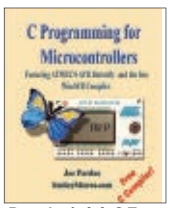
## BOOK & KIT COMBOS



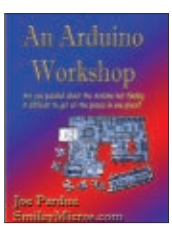

Book **$44.95**

**From the Smiley Workshop C Programming for Microcontrollers**
by Joe Pardue

Kit **$66.95**

Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATMEL's AVR Butterfly board and the FREE WinAVR C compiler to make a very inexpensive system for using C to develop microcontroller projects.

**Combo Price $99.95 Plus S/H**




**From the Smiley Workshop An Arduino Workshop**
by Joe Pardue

The book *An Arduino Workshop* and the associated hardware projects kit bring all the pieces of the puzzle together in one place. With this, you will learn to: blink eight LEDs (Cylon Eyes); read a pushbutton and 8-bit DIP switch; sense voltage, light, and temperature; make music on a piezo element; sense edges and gray levels; optically isolate voltages; fade an LED with PWM; control motor speed; and more!

**An Arduino Workshop Combo**

**Reg Price $ 124.95** **Subscriber's Price $119.95 Plus S/H**

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# PROJECTS

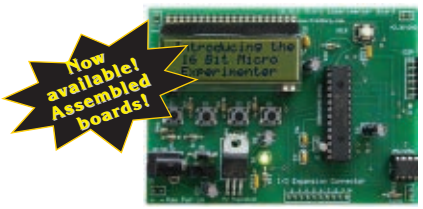
## Mini-Bench Supply Complete Kit

A small power supply with +5V, +12V, and -12V outputs is a handy thing to have around when you're breadboarding circuits with both op-amps and digital ICs.

Kit includes: Enclosure box, accessories, DC-to-DC converter kit, switching regulator kit, and article reprint. For more information, please see the "feature article section" on the top right side of the *Nuts & Volts* website.

Subscriber's Price **$76.95**
Non-Subscriber's Price **$83.95**

## 16-Bit Micro Experimenter Board




Ready to move on from 8-bit to 16-bit microcontrollers? Well, you're in luck! In the December 2009 *Nuts & Volts* issue, you're introduced to "the 16-Bit Micro Experimenter." The kit comes with a CD-ROM that contains details on assembly, operation, as well as an assortment of ready-made applications. New applications will be added in upcoming months.

Subscriber's Price **$55.95**
Non-Subscriber's Price **$59.95**

## Piezoelectric Film Speaker Kit

NEW!

As seen in the November issue, here is a great project to amaze your friends and to demonstrate a unique way of producing sound. Kit contains one piece of piezoelectric film, speaker film stand, PCB, components, audio input cable, and construction manual. All you'll need to add is a battery and a sound source. For more info, please visit our website.

Subscriber's Price **$69.95**
Non-Subscriber's Price **$74.95**

## Garage Door Alarm PCB & Chips

***As seen in the November 2010 issue.***

**Is Your Garage Door Open?**

This project uses the latest in wireless technology, and is a fun and easy project to build. We provide the difficult parts: the transmitter and receiver PCBs with their matching programmed MCUs. The other components can be fould at your favorite parts house.

**Includes an article reprint.**

Subscriber's Price **$29.95**
Non-Subscriber's Price **$31.95**

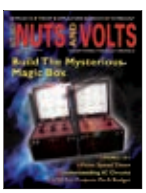
## Xmas Tree Kit

The microprocessor-controlled Xmas Tree comes with 8 preprogrammed light display sequences. All you need is a soldering iron and a couple of batteries, and you'll be ready to show off your electronic tree!

**To see a demo video, please visit www.nutsvolts.com**

Subscriber's Price **$38.95**
Non-Subscriber's Price **$41.95**

## Magic Box Kit




***As seen on the April 2007 cover***

This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship. This clever trick has the observer remove one of six pawns while you are out of the room and upon re-entering you indicate the missing pawn without ever opening the box.

**Includes an article reprint.**

Subscriber's Price **$39.95**
Non-Subscriber's Price **$45.95**

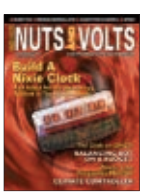
## rCube Talking Alarm Clock Kit

***As seen on the May 2009 cover***

Available in blue, black, red, and green. All components are pre-cut and pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.

Subscriber's Price **$49.95**
Non-Subscriber's Price **$54.00**

## Nixie Tube Clock Kit




*October 2006*

Nixie tube clocks fuse the spirit, drama, and eerie beauty of cold war technology with modern inner works to create uncommon handcrafted timepieces.

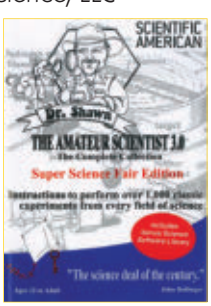
**Now with optional case choices!**
**Get more info @ our webstore.**

**Kit includes article reprint, complete instructions, and parts list**

Subscriber's Price **$146.95**
Non-Subscriber's Price **$159.95**

## The Amateur Scientist 3.0 The Complete Collection

by Bright Science, LLC




There are 1,000 projects on this **CD**, not to mention the additional technical info and bonus features. It doesn't matter if you're a complete novice looking to do their first science fair project or a super tech-head gadget freak; there are enough projects on the single CD-ROM to keep you and 50 of your friends busy for a lifetime!

**Reg Price $26.95**
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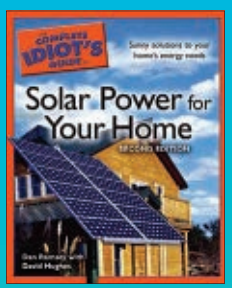
*WE ACCEPT VISA, MC, AMEX, and DISCOVER. Prices do not include shipping and may be subject to change.*

***Attention*** **Subscribers ask about your discount on prices marked with an ***

# The Nuts & Volts **WEBSTORE**

## ALTERNATIVE ENERGY SECTION

### The Complete Idiot's Guide to Solar Power for Your Home
by Dan Ramsey / David Hughes




The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems.
**$19.95**

NEW!

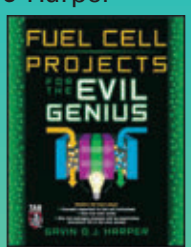
### Green Lighting
by Brian Clark Howard, Seth Leitman, William Brinsky
**Flip the switch to energy-efficient lighting!**

This do-it-yourself guide makes it easy to upgrade residential and commercial lighting to reduce costs and environmental impact while maintaining or even improving the quality of the lighting. Filled with step-by-step instructions and methods for calculating return on investment, plus recommended sources for energy-efficient products.
**$24.95**

### 50 Green Projects for the Evil Genius
by Jamil Shariff

Using easy-to-find parts and tools, this do-it-yourself guide offers a wide variety of environmentally focused projects you can accomplish on your own. Topics covered include transportation, alternative fuels, solar, wind, and hydro power, home insulation, construction, and more. The projects in this unique guide range from easy to more complex and are designed to optimize your time and simplify your life!
**$24.95**

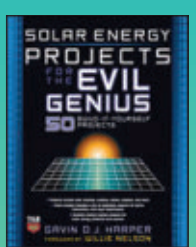
### Fuel Cell Projects for the Evil Genius
by Gavin D J Harper




FUEL YOUR EVIL URGES WHILE YOU BUILD GREEN ENERGY PROJECTS!

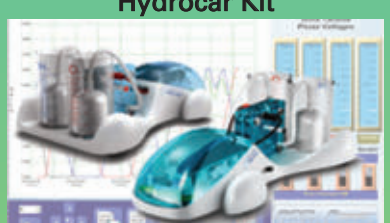
Go green as you amass power! Fuel Cell Projects for the Evil Genius broadens your knowledge of this important, rapidly developing technology and shows you how to build practical, environmentally conscious projects using the three most popular and widely accessible fuel cells!
**$24.95**

### Solar Energy Projects for the Evil Genius
by Gavin D J Harper




Let the sun shine on your evil side — and have a wicked amount of fun on your way to becoming a solar energy master! In *Solar Energy Projects for the Evil Genius*, high-tech guru Gavin Harper gives you everything you need to build more than 30 thrilling solar energy projects. You'll find complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin.
**$24.95**

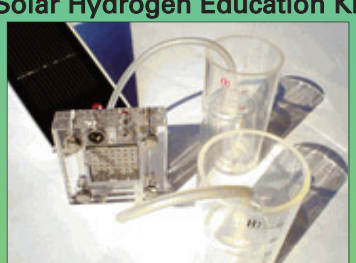
### Hydrocar Kit



The Hydrocar is used in a couple of great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 10 and 11, he teaches you the operation of the Polymer Electrolyte Membrane "reversible" fuel cell. For kit details and a demo video, please visit our webstore.

Subscriber's Price **$79.95**
Non-Subscriber's Price **$84.95**

### Solar Hydrogen Education Kit



The Solar Hydrogen Education Kit includes a solar cell, a PEM reversible fuel cell, oxygen and hydrogen gas containers, and more! The set only needs pure water to create hydrogen and produce electricity. Perfect for science labs, classroom use, or demonstration purposes.

Subscriber's Price **$56.95**
Non-Subscriber's Price **$59.95**

### Windpitch Kit

The WindPitch Wind Turbine Kit is a miniature real-working wind turbine and is one of the great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 8 and 9, he teaches you how to produce the most power by evaluating the pitch (setting angle) of the profiled blades. For kit details, please visit our webstore.

Subscriber's Price **$84.95**
Non-Subscriber's Price **$89.95**

# >>> QUESTIONS

### Circuit Design Assistance

I am trying to design a voltage monitoring circuit that will monitor a 12 VDC solar battery that is a little larger than a car battery. The input voltage signal range needs to be linear, starting no lower than 3 VDC and up to 15 VDC. The output signal needs to be 4 to 20 mA ... 4 mA is 3 VDC and 20 mA is 15 VDC. On my schematic (**Figure 1**), I would like to vary the voltage input at V1 and have the output at R2, or something like that. I was not able to figure out how to get the circuit to produce my desired output results without the use of a second voltage source set to 4 VDC. If at all possible, I prefer to have no power sources other than the primary source being monitored. Please help me improve the circuit and solve this extra unwanted powering problem. Also, recommend any alternative components that have lower power requirements.

**#12101** **James McAndrew**
**Lafayette, LA**

### Garage Door Remote Control

My garage door opener remote operates using a carrier frequency designated W, with modulating frequency 52. Since it is now inoperative (with a fresh nine volt battery), how may I begin to repair or replace either the transmitter or receiver? The manual control connected to the receiver works fine.

I've done a fair amount of electronic circuit design and repair, but nothing in this frequency range which I believe is up in the MHz range. I'd like to not have to replace the entire door opener.

**#12102** **P. Kaltenborn**
**Fair Haven, NJ**

### EHT With An Op-Amp
### CONAR 251 Scope Info

**1)** I need to know how to use an EHT with an op-amp or the components around either a CA3140 op-amp or a LM358 to change the output Z of an EHT stick. I want to use it with other test equipment — like a frequency counter or oscilloscope — to make sure I have a sine output of a flyback from an amp that I'm working on. Or, other suggestions to change the Z output.

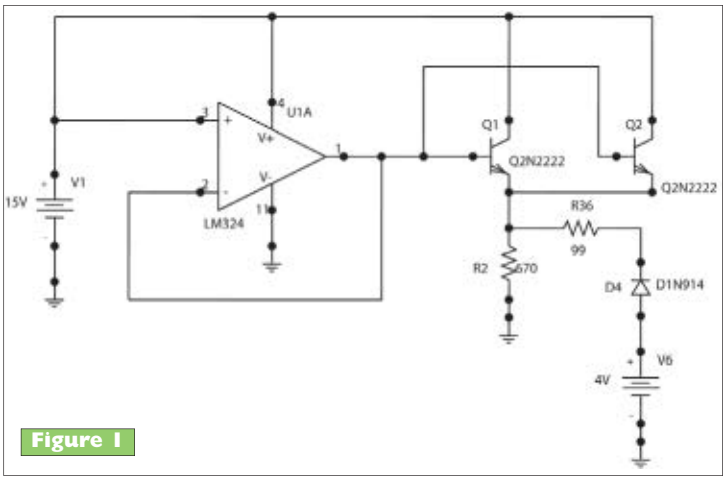


Figure 1

**2)** Where can I find out the value of a fuse for the CONAR Model 251 oscilloscope and/or where can I get a manual or schematic for this scope? (CONAR was bought out by the National Radio Institute - McGraw Hill Continued Education which is no longer in business.) I want to power up this scope and test its output. I need to know the fuse type and amps before I test it, as money is in short supply. Or, is there a website to find this information?

**#12103** **James New**
**Jacksonville, FL**

### Clickers and Clackers

What are the most appropriate, readily-available, low-cost, low-power, and reliable radio transmitters, receivers, microcontrollers, and USB modules or chips for building clickers and clackers defined as follows?

*A clicker* is a handheld box with eight buttons and one of 32 codes. The box contains a microprocessor, a radio transmitter, and an easily replaceable battery power supply. When a button is pressed, the clicker radio transmitter emits one byte of data, identifying the button with three bits and the clicker with five bits. Transmitter range needs to be no more than 200 feet.

*A clacker* is a device in a small box containing a radio receiver and a microprocessor that is powered by and corresponds via USB with an application program running under Windows XP (or later Microsoft OS). The application program user interface includes a start button and a stop button. The program maintains in RAM a 32 row by eight column bit array and is normally in an idle loop waiting for the start button to be pressed. When the start button is pressed, the array is set to all 0s and the program enters a loop, ready to receive data bytes from up to 32 clickers. If a byte arrives, then a 1 is entered in the correct row and column of the clicker code and clicker button. When the stop button of the user

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving technical problems. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals.

***Always use common sense and good judgment!***

Send all questions and answers by email to **forum@nutsvolts.com**
*Check at **www.nutsvolts.com** for tips and info on submitting to the forum.*

interface is pressed, then the array is recorded as a (sequentially numbered) CSV file on the hard disk in a previously designated folder. Then, the program re-enters its idle loop waiting for the start button to be pressed. I know how to solder and build hardware, and how to program; I need advice on what modules to use.

**#12104** **E. D. Cooper**
**Rockport, MA**

# >>> ANSWERS

**[#7105 - July 2010]**
**Sensor Matrix To Detect Objects**

***1.*** *I'm looking for a low cost ($1 - $2) optical sensor solution to detect the presence of an object in a bin. The size of a bin varies between 5 cm to 15 cm. Sensor and LED light source would therefore need to be that far apart.*

***2.*** *Bins are grouped in a matrix of eight by 20, and their status needs to be collected periodically. What kind of a circuit would be the easiest way to collect the status of all bins?*

Because the number of bins can be in the hundreds, I suggest a system that uses a webcam or a security camera setup where many (100 or so) bins are "watched" by a common viewer. Object shape recognition could be added to the software.

If the objects are metallic and the bins are non-metallic, a printed circuit coil(s) could be mounted under each bin and each sequentially interrogated as is done with a metal detector.

I don't recommend your optical solution because of variations in ambient light, dirt, aging, aiming, tolerances, etc.

**William A. Hanger**
**Churchville, VA**

**[#8101 - August 2010]**
**Heating Element Control Circuit**

*I'm looking for a control circuit (120 AC) for an electric smoker heating element that doesn't have the wide temperature swings a normal thermostat controller has. It would need to be rated to at least 15 amps. For example, using a 210-220F range:*

***1.*** *Below 210F — Heating element is at full power.*

***2.*** *Between 210-220F — Power ramps down as the temperature nears 220F.*

***3.*** *Above 220F — Heating element is off or at the lowest power setting.*

**1.** What you are looking for is called a "proportional temperature controller." In such a circuit, there is a linear band a few degrees wide in which the power delivered to the heating element is inversely proportional to the error in the temperature.

In this range, being a degree low will result in say, 50% power being supplied to the heating element, and being a degree high will result in 25% power. Outside of this narrow band, the heater is either on or off.

So, when starting up, the heater comes on full, and then as the temperature approaches the setpoint, the power is gradually backed off, resulting in fast warm-up, small overshoot, and tight temperature control.

Fortunately, there are many ICs that do this; the UA2016 from ON Semi is one that is cheap, easy, and available: **www.onsemi.com/PowerSolutions/product.do?id=UAA2016PG**

**Robert Zusman**
**Scottsdale, AZ**

**2.** Your real control problem is that the 15 amp 120V heating element at full heat needs 1,800 watts, and at minimum heat, a linear controller would need to waste 1,700 + watts.

You say it is a food smoker (not a meth lab). I do not believe that the smoker really needs full proportional control, and a commercial controller would be very expensive. You are unhappy with the existing full-on-full-off thermostat control so consider this alternative. This method is strictly "electrical" and does not need expensive solid-state controls to be fried or damaged by rain or lightning surges.

This simple alternative would be to buy two 15 amp thermostat switches and two more 1,800 watt heating elements at your local appliance store, mount and wire the three elements in series, and wire the two thermostat switches — each across one of the added elements for one-third, two-thirds, or full power.

One added thermostat switch would be adjusted to close below your lowest temperature shorting one element; the second added thermostat would be adjusted to short the second element at a higher setpoint.

*Operation:* Starting from cold, you would have the two added elements shorted by their thermostat switches and the full voltage (1,800 watts) to the original heating element. As the temperature reached a lower setpoint, the lowest thermostat would open up and the first extra element would be inserted into the circuit.

Two elements still in the circuit = double the resistance = half the current = half the heat. When the temperature reaches the "hold" temperature, the upper thermostat would open up and the third element would be in the circuit.

Three elements = triple the resistance = one-third the current = one-third the heat.

As a hungry or curious someone opens the lid, cooling would cause the extra elements to be switched out, thereby going back to high power until it catches up. By adjusting the thermostat switches and leaving existing safeties in place, you can get the control you need for the smoked Christmas turkey or venison at a much lower cost than an industrial control capable of wasting 1,700 watts as heat or generating 1,800 watts of switching radio noise when the smoker is at the high temperature.

**Patrick Hamel**
**via email**

worldmags

**[#8104 - August 2010]**
**MSN Direct**

*My coffee maker works off the MSN Direct signal. Two more years and MS turns it off. Is there a way to build the FM generator with the time in the signal so my coffee maker can at least wake me up with coffee already brewed?*

The objective is to have coffee on time and feel good that you did it yourself. Forget the outside signal, disconnect it.

Look around *Nuts & Volts* advertisers and find a clock kit that will fit where you want to put it. Use the alarm circuit and a solid-state relay to control the coffeepot.

You will have coffee, the feeling of accomplishment, and freedom from outside interference (when some other company uses that same "abandoned" signal for another purpose).

**Patrick Hamel**
**via email**

**[#9101 - September 2010]**
**Milwaukee Screwdriver Battery Chargers**

*I am a soon to be retired industrial electrician. At work, we use many cordless screwdrivers, mostly Milwaukee and Dewalt. I have several no longer functional 48-59-0180 chargers. It looks like a relatively simple circuit. I haven't indentified an in-line chip. Can anyone help with schematics and components?*

*Replacement 48-59-180s are no longer available. Replacement 48-59-300s are available, but at half the cost of an entire screwdriver kit.*

One option might be the charger modules at **www.batteryspace.com**. If you drill down under battery chargers, you'll find circuit boards for various voltages, one of which is auto select for 2.4 to 7.2V. It needs a 12-16 VDC input and is listed for $12.95. A 500 mA+ wall wart could be used as a supply if there is not a suitable supply in the existing charger.

**Steven Hodges**
**via email**

**[#9103 - September 2010]**
**Electric Fence Monitoring**

*I currently operate a small 10 acre hobby goat farm, protected by a commercial 16 KV, high impedance, pulsed charge, electric fence spanning across rolling hills which are "not visible" from the house. Some of our goats are natural born escape artists — as determined to get out as coyotes and wildcat predators are to get in. I need a "smart circuit" that can detect whether: **(1)** animal fence contact was just a "one time" brief encounter (resulting in a successful rebuff); **(2)** there are multiple successive contacts within a set time period (as would be the case of a determined assailant); **(3)** there is a persistent reduced fence charge (from an entangled animal); or **(4)** there is a total fence failure (due to a break in or total grounding of the system). Most importantly, the circuit must be able to identify which specific fence segment/zone the problem is located at for fast response. In the past, predators have patrolled just outside the fence eventually digging underneath it or jumping over it without contacting it, so some form of zone based non-contact perimeter sensing (possibly using air to wire capacitive couplings) would allow for early warning of a potential problem.*

While it might be possible to identify which zone the problem is at, you may want to take a step back and consider an approach that does not rely only upon the fence charging system. In fact, I'd suggest "taking a step back" and looking at the entire problem again.

As I see it, the problem statement is: *There is a physical barrier which is intended to keep animals on either side of the barrier from crossing the barrier to the other side, and the barrier is not completely effective. Animals on either side of the fence must either be kept from crossing the barrier, or a means of detecting such a crossing (with associated location identification) and notifying a human must be implemented.*

I can see a couple of possible approaches, not necessarily mutually exclusive.

First, could the barrier be made more effective? You mention predators getting over or under it — should it be extended in both directions? Perhaps a different barrier entirely?

Second, assuming that the electric portion of the barrier is kept, detecting a failure on the wire is probably a good thing. You did not mention if it has separate zones itself, or if you were planning to create them somehow. I'd avoid messing with the fence system much other than to create some sort of simple 'loss of power'

| Pin | T568A Pair | T568B Pair | Wire | T568A Color | T568B Color | Pins on plug face (socket is reversed) |
|---|---|---|---|---|---|---|
| 1 | 3 | 2 | Tip | wht/green stripe | whr/orange stripe | |
| 2 | 3 | 2 | Ring | green solid | orange solid | |
| 3 | 2 | 3 | Tip | wht/orange stripe | wht/green stripe | |
| 4 | 1 | 1 | Ring | blue solid | blue solid | |
| 5 | 1 | 1 | Tip | wht/blue stripe | wht/blue stripe | |
| 6 | 2 | 3 | Ring | orange solid | green solid | |
| 7 | 4 | 4 | Tip | wht/brown stripe | wht/brown stripe | |
| 8 | 4 | 4 | Ring | brown solid | brown solid | |

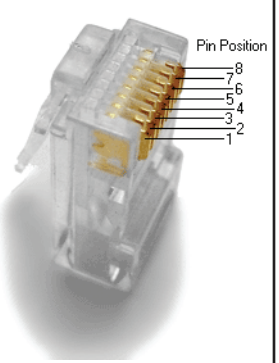



Figure 2

detector for each 'leg' of the fence. Since its pulsed, you could probably create some sort of 'missing pulse' detector (the old retriggerable monostable trick), just be sure to drop that 16 kV down to something safe.

However, rather than trying to detect fence events, it seems like a more robust approach would be to add some sort of motion detection for both sides of the barrier. And, indeed, I'd suggest a 'fence integrity violation' detection capability. I am imagining an array of mirrors arranged such that you get a 'curtain' of light alongside the wires, with a laser at one end of the curtain and some sort of photo detector at the other. If you extend the light curtain above the fence, you could detect jumping events (but you might also detect birds landing on the wires!). Maybe a combination of traditional motion detection (sonar, IR, or radar) to enable the notification from light curtain events.

If you had two fences (pretty close together), you could detect ANY motion inside that 'no animal zone' and declare an event (somehow you need to ignore birds, though).

**Rusty Carruth**
**Tempe, AZ**

**[#9107 - September 2010]**
**Keystone Jack Wiring**

*I need data/instructions on how to wire a keystone jack per specs 368A/B.*

EIA/TIA 368 is a standard for frequency division multiplexing. I am going to assume you mean EIA/TIA 568A/B

From **http://en.wikipedia.org/wiki/T568A#Wiring**; see **Figure 2**.

Note that the only difference between T568A and T568B is that pairs 2 and 3 (orange and green) are swapped. Both configurations wire the pins "straight through," i.e., pins 1 through 8 on one end are connected to pins 1 through 8 on the other end. Also, the same sets of pins are paired in both configurations: pins 1 and 2 form a pair, as do 3 and 6, 4 and 5, and 7 and 8. One can use cables wired according to either configuration in the same installation without significant problem; problems involving crosstalk can occur (which is normally minimized by correctly twisting a pair together), but are usually insignificant in all but the most stringent specifications such as Category 6 cable. The primary thing one has to be careful of is not to accidentally wire the ends of the same cable according to different configurations (unless one intends to create an ETHERNET crossover cable).

Another quick tip: The wires should alternate across the connector: striped, solid, striped, solid, striped, solid, striped, solid.

**Daniel De Jager**
**Edgewood, WA**

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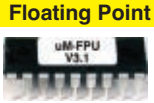


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| Specifications | DSO-2090 | DSO-2150 | DSO-2250 | DSO-5200 /5200A |
|---|---|---|---|---|
| Channels | 2 Channels | | | |
| Impedence | 1M 25pF | | | |
| Coupling | AC/DC/GND | | | |
| Vertical resolution | 8 Bit | | | 9 Bit |
| Gain Range | 10mV-5V, 9 Steps | | | 10mV-10V, 10Steps |
| DC Accuracy | +/- 3% | | | |
| Timebase Range | 4ns - 1h 38 Steps | | | 2ns-1h, 39 Steps |
| Vertical adjustable | Yes | | | |
| Input protection | Diode clamping | | | |
| X-Y | Yes | | | |
| Autoset | 30Hz~40MHz | 30Hz~60MHz | 30Hz~100MHz | 30Hz~200MHz |
| EXT. input | Yes | | | |
| Trigger Mode | Auto / Normal / Single | | | |
| Trigger Slope | +/- | | | |
| Trigger Level Adj. | Yes | | | |
| Trigger Type | Rising edge / Falling Edge | | | |
| Trigger Source | Ch1 / Ch2 / EXT | | | |
| Pre/Post trigger | 0-100% | | | |
| Buffer size | 10K-32K per ch | | | 10K-512KB per ch |
| Shot Bandwidth | DC to 40MHz | DC to 60MHz | DC to 100MHz | 100MHz |
| Max Sanple Rate | 100MS/s | 150MS/s | 250MS/s | 200MS/s / 250MS/s |
| Sampling Selection | Yes | | | |
| Waveform Display | port/line, waveform average, persistence, intensity | | | |
| Network | open / close | | | |
| Vertical Mode | Ch1, Ch2, Dual, Add | | | |
| CursorMeasurement | Yes | | | |
| Spectrum Analyzer | | | | |
| Channels | 2 Channels | | | |
| Math | FFT, addition, subtraction, multiplication, division. | | | |
| Bandwidth | 40 MHz | 60 MHz | 100MHz | 200 MHz |
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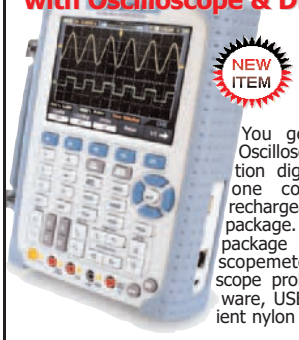


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## BlackJack SolderWerks

### Hot Air System with Soldering Iron & Mechanical Arm

The BK5000 from BlackJack SolderWerks provides a very convenient combination of hot air and soldering in one compact package. The hot air gun is equipped with a hot air protection system which provides system cool-down and overheat protection. The system cool-down feature removes the residual heat from the nozzle after the hot air function is switched off. This will cool the nozzle more rapidly & extend the life of the heating element. The overheat protect feature effectively shuts off power to the heater when an overheat in the middle of the handle has been detected. The hot air gun is designed to use different SMD nozzles for various SMD applications. The soldering iron incorporates a replaceable tip design & uses the same series of tips that are compatible with BlackJack models BK2000 & BK2000+

Mechanical Arm with Air Gun attached

SPECIFICATIONS:

Power Input : 110V
Dimensions: 188mm (w) x 126mm (h) x250mm (d)
Weight: 4.8Kg

SOLDERING IRON
Power Consumption: 35W
Temperature Range: 200 - 480 degrees Celsius
Heating Element with Tip: Ceramic Heater
Output Voltage: 24V
Tip to Ground Resistance: Below 2 ohms
Tip to Ground Potential: Below 2mV

HOT AIR
Power Consumption: 500W peak
Temperature Range: 100 - 500 degrees Celsius
Heating Element Metal Heating Core
Nozzle to Ground Resistance: Below 2 ohms
Pump/Motor Type: Diaphragm Pump
Air Capacity: 23 L /min (max)

Chtistmas Special!

A wide selection of accessories, soldering tips & hot air nozzels are also available

**Item # BK5000** **$97.00**

www.circuitspecialists.com/bk5000

## 0-30V / 0-5A . DC Power Supply

The CSI530S is a regulated DC power supply which you can adjust the current and the voltage continuously. An LED display is used to show the current and voltage values. The output terminals are safe 4mm banana jacks. This power supply can be used in electronic circuits such as operational amplifiers, digital logic circuits and so on. Users include researchers, technicians, teachers and electronics enthusiasts. A 3 ½ digit LED is used to display the voltage and current values.

ww.circuitspecialists.com/csi530s

**Item # CSI530S** **$84.95**

# Perfect your Propeller Projects!

*The multicore Propeller P8X32A microcontroller provides eight 32- bit processors each with two counters, its own 2 KB local memory and 32 KB shared memory. We offer wide range of kits and accessories to help you maximize the power of the Propeller!*

**Propeller Education Kit - $99.99**
- **40-Pin DIP Version (#32305)**
- **PropStick USB Version (#32306)**

The best way to learn Propeller programming is by following the lessons in the Propeller Education Kit Labs: Fundamentals, included in this kit.

We offer a variety of **easy-to-interface sensors** to enhance the capabilities of your project.

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The **Propeller Proto Boards** are a low-cost, high-quality solution for permanent Propeller projects. We recommend a Prop Plug (not pictured; #32201; $14.99) for use with the Serial board.
- **Serial Version (#32212; $24.99)**
- **USB Version (#32812; $29.99)**

**Programming Board Enclosures ($19.99 each)** are designed to fit most 3 x 4" Parallax programming boards including the Propeller Broto Boards. Protect your board and the circuits on it with style!
- **Clear (#721-32212)**
- **Opaque Red (#721-32214)**
- **Transparent Blue (#721-32216)**
- **Opaque Black (#721-32218)**

**Stingray Robot Kit (#28980; $299.99)** - Mid-size platform for a wide range of robotics projects and experiments. The Propeller Robot Control Board is the brains of the system providing a multiprocessor control system capable of performing multiple tasks at the same time.

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